OMA

Astronomical

PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.

VOLUME XIX.

1907.

SAN FRANCISCO:
PRINTED FOR THE SOCIETY.
1907.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, FEBRUARY 10, 1907. No. 112

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[See *Publications* A. S. P., Vol. VIII, p. 101.]

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The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
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The Record-Union, Sacramento, California.
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METHODS OF MEASUREMENT AND REDUCTION OF SPECTROGRAMS FOR THE DETERMINATION OF RADIAL VELOCITIES.

By J. H. Moore.

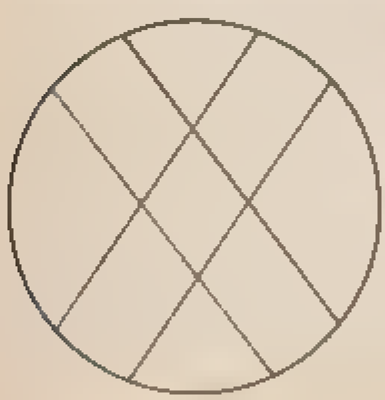
There is probably no field of astronomy in which the development of instruments and methods has been so rapid as in the application of the spectroscope to the determination of the radial velocities of stars according to the Doppler-Fizeau principle. In the first investigations made by Huggins in 1867, and by Vogel in 1872, the observations were visual, and it was not unusual to obtain discrepancies in the results amounting to as much as the quantities to be measured. Observations of value date from the application, by Vogel in 1887, of the photographic method to this problem, a method which had already achieved remarkable results in the hands of Professor Pickering in his qualitative studies of stellar spectra. Following this and the subsequent improvement in design of spectrographs and methods of reduction in which Professor Campbell at the Lick Observatory led the way, there has been a continual development in the instrumental and observational side giving spectrograms of greater accuracy. At the same time refinements have been introduced into the methods of measuring and reducing these spectrograms in order to obtain from them velocities as accurate as the plates will warrant. It will be the purpose of the present article to outline the various methods which have been used for the measurement and reduction of spectrograms for radial velocity determinations and to discuss the advantages and limitations of each.

A stellar spectrogram for this purpose consists of a star spectrum and a comparison spectrum produced by a known source, such as the metallic arc, spark, or vacuum-tube discharge. The light from the star and the artificial source are made to pass over equivalent optical paths in the spectrograph and the spectra of the two brought to a focus on the photographic plate in such a way that the star spectrum falls in the center and the comparison spectrum on each side of it. In most astronomical spectrographs of high dispersion only a

comparatively short section of the spectrum (about three or four hundred tenth-meters) is in sharp focus. With these instruments we utilize only the part of the spectrum to which the photographic plate is extremely sensitive. Fortunately this region is as rich in lines as any other part of the spectrum, and is about the one of maximum dispersion of glass prisms consistent with permissible loss of light by absorption. In some spectrographs the prisms are set at minimum deviation for λ 4340, in others at λ 4500, or for some point intermediate between these wave-lengths. The measurable spectrum extends from about λ 4230 to λ 4400 in the first case, and from about λ 4340 to λ 4630 in the second case. For comparison spectrum a metal is chosen which is rich in lines for the region used. For example, iron is generally chosen for the former, while titanium and vanadium are employed for the latter region. The positions on the plate of the lines in the star spectrum (*i. e.* their wave-lengths) are, according to the Doppler-Fizeau principle, affected by the relative velocity of the star and the observer in the line of sight, while the wave-lengths of the comparison lines are unaffected by such velocity, their source being on the instrument. The radial velocity of the star is determined by measurement of the relative positions of the lines in the two spectra.

MEASUREMENT OF PLATES.

Most line-of-sight observers have employed for the measurement of spectrograms either the Töpfer engine, or the one designed by Professors HALE and FROST and made by GAERTNER. It is necessary first to test for the errors of the screw, and if they are comparable with the error of setting on lines of the spectrum they must be taken into account. Most observers use one vertical wire for making the settings. The accuracy of settings on strong comparison lines is increased, according to FROST, by the use of two parallel vertical wires, but such a form is seldom used. A reticle of the form shown in the figure, sometimes used in the measure of grating plates, possesses points of advantage over either of the other forms.



The method of measuring a plate varies somewhat with

different observers, but, with the exception of the use of the Hartmann spectrocomparator, is briefly as follows: The plate is placed on the engine (usually with violet apparently left), properly aligned, and so adjusted that the reading on a selected comparison line shall be some arbitrary one agreeing with the standard table to be used for reduction. Settings are made continuously along the plate on good star and comparison lines as they chance to occur. The plate is then reversed and the settings repeated, the plate being so adjusted, for convenience, that the reading on the first comparison line in the second position shall equal a constant (say 100) minus the reading on the same line in the first position. The effect of errors due to personal equation is, according to the investigations of Professor LORD and Professor BELOPOLSKY and the more exhaustive ones of Dr. REESE,[1] practically eliminated by taking the mean of the measures of the plate in the two positions. It should be noticed, however, that in the reversal of the plate the spectrum is also inverted, which might so change the appearance of lines as to interfere with the elimination of personal equation in this way. Curvature of the spectrum lines may also interfere in like manner with the elimination of this source of error. The effect of accidental errors in setting on lines is reduced by employing a number of lines. Care should be taken to maintain the engine at as nearly a constant temperature as possible, and especially to keep the illumination of the plate the same during the entire measure.

METHODS OF REDUCTION.

Professor VOGEL in his early work used only the $H\gamma$ line for comparison, and measured the displacement between the $H\gamma$ of the star spectrum and that of the vacuum tube. Later, for stars of the solar type he employed the iron spectrum for comparison, and measured the displacement between the iron lines in the star and comparison spectra. This gave only about eight or ten independent measures of the displacement, so that in the case of stars rich in lines, as those of the F to M types, he was using only a very small part of the material on each plate and not making the best possible selection of lines. Methods have been devised, however, which enable us to use other lines in the star spectrum than those corresponding

[1] *L. O. Bulletin* No. 15, and *Astrophysical Journal*, Vol. 15, 208, 1902.

to the comparison spectrum. These may be grouped under the following heads: I. Methods of interpolation by dispersion formulæ; II. The velocity standard method; III. The spectro-comparator method.

I *Methods of Interpolation.*—Methods of interpolation were introduced by Professor CAMPBELL in 1896 (not published until 1898[1]) and by Professor HARTMANN in 1898,[2] which made it possible to use all the stellar lines on the plate, provided their wave-lengths are known. This is accomplished by the aid of a table of micrometer settings corresponding to the wave-lengths of the lines employed. The relation between wave-length and the corresponding micrometer setting is expressed by means of a dispersion formula, the constants of which are determined from the measures of lines of known wave-length in a spectrum of a source whose radial velocity is approximately zero,—for example, the Sun.

In explaining this method we shall first assume that it is possible to obtain a formula which shall accurately represent the relation existing between wave-lengths and micrometer readings for the whole region of spectrum to be used, and that such a table has been formed from our Sun plate, leaving to a later paragraph the discussion of the formulæ actually used by CAMPBELL and by HARTMANN.

λ	Sun	rV_s
4338.084	10.258	299
4340.634	10.846	300
.	.	.
4351.930	13.433	304
.	.	.
4501.448	43.723	367
.	.	.
4656.644	69.215	434

We have, then, a table we shall call our standard dispersion table. In the first column under λ are given the wave-lengths of the lines of the Sun taken from ROWLAND'S Preliminary Table of Solar Wave-Lengths. The second column contains the micrometer readings corresponding to the wave-lengths of the first column. These settings are computed from the constants of the Sun plate. The third column contains the values of rV_s, the factor for each line by which the displacement is multiplied in order to obtain the corresponding velocity in kilometers per second; V_s, the velocity in kilometers per second corresponding

[1] *Astrophysical Journal*, Vol. 8, 123, 1898.

[2] *Astrophysical Journal*, Vol. 8, 218, 1898; *Astronomische Nachrichten*, Vol. 155, [illegible], 190.

to a displacement of one tenth-meter $= \frac{\text{velocity of light}}{\text{wave-length}} = \frac{299800}{\lambda}$. The quantity r, the number of tenth meters in one revolution of the screw, is obtained from the original constants of the dispersion formula Its value will be deduced later.

In measuring the star plate, set it so that one of the comparison lines—say 4338.084—has the tabular micrometer reading 10.258, and make the settings on the other comparison and star lines as described above. Take the difference, micrometer reading of comparison line on star plate minus micrometer reading of same comparison line in our table (under Sun). Next plot a curve with wave-lengths as abscissæ, and these differences as ordinates. Construct a table of micrometer settings (for zero velocity) for star lines measured on the plate by applying to the tabulated settings for these lines corrections read off from the curve. Suppose, for example, we wish to obtain the reading for the line 4351.930 on a star plate (*i. e.* the reading which this star line would have if unshifted by radial velocity) We read off from the curve the difference corresponding to λ 4351.930 and add it to the micrometer reading 13.433 in the table Suppose it is + .022. Then the reading for zero velocity would be 13.455, and if the micrometer setting of this line on the star plate is 13.330, then the displacement is — .135 Where there are comparison lines corresponding to star lines some observers take the difference between the micrometer readings directly for the displacements, while others rigorously follow the process just outlined. Having now the displacements for each of the stellar lines measured it is necessary to multiply each one by the corresponding rV_1 in order to obtain the velocity The mean of the velocities obtained from the different lines, which we may call v_1, is the relative velocity of the star and observer in the line of sight. It is necessary to apply two small corrections to v_1: a correction for scale and a correction for curvature of the spectrum lines If the dispersion of the star plate differs greatly from that of the dispersion table, the values of r in the table will be too large or small for the star plate. In place of computing the r for each line we apply a correction to v_1, obtained as follows: Let a be the difference between the tabular micrometer readings

of the first and last comparison lines used, and b the difference in the actual settings on the plate for these same comparison lines, then the correction for scale $= \frac{a-b}{a} \cdot v_s$. It has the same sign as v_s if $a > b$ and opposite if $a < b$. The correction for curvature of the spectral lines may be computed by DITSCHEINER'S formula,[1] which has been found by ADAMS[2] to be accurate for long slits. Some observers determined this correction empirically from lines in the solar spectrum on the assumption that the curve is a parabola. The effect of curvature is eliminated in the new Mills spectrograph by using a curved slit which gives straight spectral lines.

In order to reduce this value of the radial velocity to the Sun, the corrections for the annual and diurnal motions of the Earth are computed from the formulæ given by Professor CAMPBELL in FROST-SCHEINER, pp. 338-345.[3] If v_a be the correction to the observed velocity of the star for the Earth's annual motion, then

$$v_a = -V_a \sin (\lambda - \odot + i) \cos \beta$$

where V_a = the Earth's velocity in kilometers per second in its orbit;

λ and β = the longitude and latitude of the star observed;

$\odot$ = the Sun's longitude at the time of observation;

$90° - i$ = the angle which the tangent to the Earth's orbit makes with the radius-vector drawn to the point of tangency.

The correction v_d due to the diurnal rotation of the Earth is given by

$$v_d = -V_d \sin t \cos \delta \cos \phi$$

where V_d = the velocity in kilometers per second of a point on the Earth's equator due to the diurnal rotation, and equals 0.47;

t = the hour angle of the star observed;

δ = the declination of the star observed;

ϕ = the latitude of the observer.

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[1] For this formula and its derivation see FROST-SCHEINER, p. 15; also, see an article by Professor LORD, *Astrophysical Journal*, Vol. 5, 348, 1897.

[2] *Astrophysical Journal*, Vol. 11, 309, 1900.

[3] See Professor SCHLESINGER'S article in *Astrophysical Journal*, Vol. 10, 1-13, 1899; also an approximate method for reductions to the Sun by Dr. PALMER in *L. O. Bulletin* No. 98, 1906; and a recent graphical method proposed by HARTMANN in *Astronomische Nachrichten*, Vol. 173, 97, 1906.

The reduction is simplified by the use of tables giving V_a and i for different values of $\odot$, and a table giving V_d for different hour angles and declinations. The value of the lunar correction is small and is usually neglected. It may amount at maximum to about .01 kilometer.

Dispersion Formulæ.—In order to determine the relation existing between wave-lengths and micrometer readings CAMPBELL[1] measured the positions of twenty-two selected lines on a plate of the solar spectrum made with the Mills spectrograph. Taking wave-lengths as abscissæ and micrometer readings as ordinates, he assumed the origin of abscissæ at λ 4330 (*i. e.* a point near the middle of the plate) and the origin of ordinates at micrometer readings 32.000 corresponding to λ 4330. If x is the difference in wave-length in tenth-meters between any line and λ 4330, he assumed that the micrometer reading of a line whose wave-length was λ $(4330 + x)$ was given by $R = 32.000 + a + bx + cx^2 + dx^3$. From the twenty-two lines as many equations resulted for the determination of the constants a, b, c, and d, which were solved by the method of least squares. The agreement between the computed and observed micrometer readings was found to be satisfactory not only for the above lines but for intermediate lines as well, throughout the whole region of spectrum employed by him (λ 4238 to λ 4442). In order to obtain the value of r in the expression rV_s, he obtained by differentiating the above formula $\frac{dx}{dR} = \frac{1}{b + 2cx + 3dx^2}$ Taking dR equal to unity dx becomes the number of tenth-meters in one revolution of the screw (*i. e.*, $r = dx$). The wave-lengths used were taken from ROWLAND'S table of solar wave-lengths, and the assumption was made that the wave-lengths of the iron comparison lines used were the same as those of the corresponding iron lines in the solar spectrum. The main objection to the use of the above formula is the great amount of labor involved in making the solution for the constants, in order that the curve should represent accurately the region of spectrum employed.

Professor HARTMANN[2] proposed a dispersion formula which

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[1] *l. c.*, p. 142.

[2] This is generally known as the Cornu-Hartmann dispersion formula. The form in which it was originally given by CORNU was with the exponent $a = 1$. The formula was arrived at, however, independently by HARTMANN, by plotting the

is quite simple and gives a curve which will represent with sufficient accuracy a long section of the spectrum. If x be the micrometer reading corresponding to the wave-length λ, then $x - x_0 = \frac{c}{(\lambda - \lambda_0)^a}$ where x_0, λ_0, c, and a are constants to be determined by observation. λ_0 and a characterize the general form of the dispersion curve and are for the same spectrograph nearly constant; c is the screw value, and is affected directly by a change in dispersion with temperature; x_0 is an additive constant which depends upon the position the plate is initially given on the measuring-engine. He determined the constant a in the following manner. Settings were made on five lines in different parts of a spectrogram of the Sun. Assuming $a = 1$, he computed from the two end lines and the middle line the values of the other constants. The residuals from the observed minus the computed micrometer readings on the other two lines were of opposite sign. An assumption of $a = 0.9$ gave smaller residuals for these two lines. From the residuals obtained, using these two values of a, it was evident that the correct value of a was about 0.6. Using this value of a, he then computed the micrometer settings for the other lines which he wished to use and found that this dispersion curve represented the observed settings within the errors of observation for the region λ 4220 to λ 4680. Beyond these points it runs off rapidly. HARTMANN computes, from plates made at different temperatures, tables for every 4° difference in temperature of the spectrograph, and uses the table nearest to the dispersion of the star plate for the reduction. With this method of procedure the correction for scale is practically negligible. The value of r is obtained by differentiation of the original formula and its value is given by $\frac{(\lambda - \lambda_0)^{1+a}}{a\,c}$ where the same constants are taken as in the original computation.

Most line-of-sight observers have adopted the Cornu-Hartmann dispersion formula for the reduction of their spectrograms, although the details of the reductions vary. In the computation of the dispersion table for the new Mills spectro-

refractive index of quartz for different wave-lengths. This curve is an equilateral hyperbola which could be represented by an equation of the above form. See Potsdam *Publications*, Vol. XII.

graph we used the formula with $a = 1$, divided the spectrum from λ 4340 to λ 4630 into three sections, and computed a set of constants from three lines for each section. The continuity of the curve was assured by taking the last lines of the first and second sections as the first lines respectively of the second and third sections. The representation of the observations was found to be satisfactory. The dispersion table of the Southern Mills spectrograph was computed, placing $a = 1$, from only three lines for the whole region. The residual differences from the observed values, when plotted against the wave-lengths as abscissæ, gave an S-shaped curve from which corrections to the computed values were read off.

Professor Frost[1] prefers to reduce each of his plates independently of any other plate: *i.e.* he computes a dispersion table for each plate. Three lines of the comparison spectrum chosen for their sharpness and for their proper spacing (one near each end and one near the middle of the spectrum) give the values of the constants λ_0, x_0, and c in the Cornu Hartmann formula where $a = 1$. He then computes the wave-lengths of the comparison and star lines measured. The differences between the computed values of the wave-lengths of the comparison lines and those given for the same lines in Rowland's tables of solar wave-lengths are taken as "corrections to comparison lines." These, aside from the accidental errors of setting, he takes as representing the departure of the formula from an exact representation of the wave-lengths. The corrections for the star lines are interpolated from the corrections for the adjacent comparison lines. He prefers to do this rather than to draw a smooth curve for the corrections to the comparison lines, fearing the arbitrary smoothing out of such a curve more than the accidental errors of settings and the more serious effects of errors in wave length of the comparison lines.

Methods of reduction which depend upon dispersion formulæ require an accurate knowledge of the wave-lengths of the lines used in both the comparison and stellar spectrum. Accurate values of the absolute wave lengths are not required, but their relative values must be well determined. For example, a relative error of ± 0.01 tenth-meter in the wave-length

[1] *Publications* of the Yerkes Observatory, Vol. II, 1903.

of any line would produce an error in the velocity for that line of nearly a kilometer. The only system of wave-lengths which is at present available for our purpose is that due to ROWLAND, and this system has been generally adopted by line-of-sight observers. It has been shown,[1] however, that errors in relative wave-length exist in ROWLAND's tables, amounting in some cases to as much as .01 or .02 tenth-meters. Furthermore the adjustment of the wave-lengths of the solar spectrum to those of the laboratory metallic spectra was not accomplished in a manner free from objections, so that systematic differences between the two result. Another difficulty arises, in the case of obtaining wave-lengths for stellar lines, due to the fact that stellar spectrographs have not sufficient resolution to separate lines which were measured as separate lines by means of the more powerful instrument used by ROWLAND. It is the practice of many observers, where two lines merge together to form one line in the star spectrum, to take the mean of the wave-lengths of the component lines weighted according to the intensities given by ROWLAND for those lines in the Sun. Wave lengths based on estimates of intensities should naturally be regarded with suspicion, and in fact we do not know until the entire plate has been reduced whether we have chosen an erroneous wave-length or not. After we have reduced a number of plates of stars of the same type, we can correct the wave-lengths of those lines which consistently give residuals of the same sign. Comparison lines which consistently fall off the curve drawn for the other comparison lines are corrected in like manner.

It is known, too, that various stellar lines and blends behave differently for stars of different types.[2] It is assumed that lines in solar-type stars have the same wave-lengths as similar lines in the Sun. In the case of other types the solar lines which occur can be used in determining the wave-lengths of the non-solar lines and blends. In this way special tables are constructed for stars of different types.

The two methods of measurement and reduction which follow eliminate the sources of errors incident to the above methods as far as it is possible to do so. The first is that due

[1] See articles by FABRY and PEROT, *Astrophysical Journal*, Vol. 15, 270, 1902; EBERHART, Ibid., Vol. 17, 141, 1903; and HARTMANN, Ibid., Vol. 18, 167, 1903.

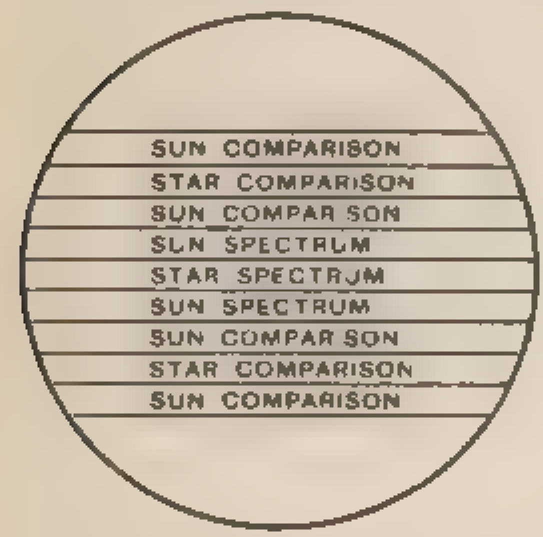
[2] S. ALBRECHT, *Astrophysical Journal*, Vol. 24, 333, 1906.

to Mr. R. H. CURTISS,[1] and is called by him "The Velocity Standard Method."

II. *The Velocity Standard Method.*—The method is in brief as follows: A standard velocity plate (*i. e.* a plate of a source whose velocity is accurately known), and the stellar plates are produced, as nearly as possible, under the same conditions of instrument, exposure, comparison spectra, etc. The measures of this standard plate fix the relative positions of the lines of the spectrum of the source and those of the comparison spectrum for a known velocity. These settings we call our zero velocity table. Now, measure the same lines, comparison and stellar, on the plate of the star whose velocity is to be determined. By a plot of the differences between the settings on the comparison lines of the standard and stellar plates the star plate is reduced to the dispersion of the standard plate. If the corrections from this plot are applied to the star lines, the differences between the measured positions of corresponding Fraunhofer lines in the standard and star spectra will be proportional to the difference of radial velocity of the sources producing them. It is usual to take a plate of the Sun or sky spectrum as the standard velocity plate, or several plates of either, all reduced to the same dispersion, from which to construct a zero-velocity table. It will be seen that the accurate wave lengths of the lines of either comparison or stellar spectrum are not required in the above process of reductions, and in fact it is necessary to know them only roughly (to about 0.1 tenth meter) for the computation of the factor rV_r. The assumption of the method is fundamental to all methods,—namely, that for solar-type stars the wave-lengths of the lines are the same as those of the corresponding lines in the Sun. For stars of other types it is necessary to form special tables for each type. The use of blends is based upon the assumption that the character of a blended line in the spectrum of a solar type star is the same as in the Sun, and is not dependent upon the estimated intensities of the component lines made by other observers. This freedom in the use of blends renders the method of great value not only to those using high-dispersion spectrographs but especially to those using low-dispersion instruments.

[1] CURTISS, *Astrophysical Journal*, Vol. 20, 149, 1904; *L. O. Bulletin* No. 62, 1904.

III. *The Spectrocomparator.*[1]—The last method to be discussed and the one most recent, is that due to Professor HARTMANN. It is in principle the same as the preceding method, except that the star plate is referred to the standard plate directly on the engine, in place of using a table of settings obtained from the standard plate. In order to accomplish this, he has designed a special form of measuring-engine known as the spectrocomparator. The instrument is provided with two plate carriages, one of which is movable. On one of the carriages the star plate is placed, and on the other, which is provided with a fine micrometer screw, is placed a standard plate of the Sun (obtained with the stellar spectrograph). The microscope has two objectives so arranged that the images of portions of the two plates are brought, by means of total reflecting prisms and a reflecting surface, to focus in the same plane and in the field of one eye-piece. Three strips of the surface of one of the prisms are silvered. These act as diaphragms in the path of rays coming from the Sun plate and as reflectors in the path of rays coming from the star plate. One of them cuts out the central strip of the Sun spectrum and throws into its place the central strip of the star spectrum. The other two cut out central strips of the comparison spectra of the Sun plate and throw into their places central strips from the comparison spectra of the star plate. The arrangement of the spectra in the field of view is as shown in the diagram.



By changing the relative magnifying powers of the two objectives he is able to produce the effect of making the dispersion of the two plates the same. The method of measurement is, then, after proper alignment of the plates, to bring corresponding sections of the two plates into the field of the microscope, set the corresponding lines of the two comparison spectra in the same straight line, and read the micrometer head. The Sun plate is then moved along

[1] Potsdam *Publications*, Vol. 18, 1906; also, *Astrophysical Journal*, Vol. 24, 285, 1906.

by the micrometer-screw until corresponding lines in the solar spectrum are in the same straight line with those of the star spectrum. The difference of the readings in the two positions is the displacement of the star lines relative to the solar lines, and is proportional to the difference in radial velocities of the star and Sun. The spectrum is divided into several sections for each of which these settings are made. The plates are then reversed and the measures repeated, care being taken that the second measure is made at a point of the screw 180° from that of the first. This method of procedure eliminates the physiological error dependent upon the positions of the plates and the periodic errors of the screw. The mean of the displacements in the two positions multiplied by the rV_r (he calls it s) for each section gives for each the value $V_* - V_0$, where V_* is the radial velocity of the star and V_0 the radial velocity of the Sun. In taking the mean,[1] the values $V_* - V_0$ for the different sections are not of equal weight, since the displacements in the violet region of the spectrum, where the dispersion is greater, are measured with a higher percentage of accuracy than those in the region of longer wave-lengths. Assume that the probable error of the measure of the line displacement is the same for all sections. Then the values $V_* - V_0 = sd$ should receive weights proportional to $\frac{1}{s}$ in taking the mean.

$$\text{The mean} = M_2 = \frac{\Sigma \frac{1}{s} (V_* - V_0)}{\Sigma \frac{1}{s}} = \frac{\Sigma d}{\Sigma \frac{1}{s}}$$

He now puts $f = \frac{1}{2 \Sigma \frac{1}{s}}$ and since $\Sigma d = \frac{1}{2} (\Sigma d_1 + \Sigma d_2)$, where d_1 and d_2 are the displacements in the direct and reverse measure, it follows that $M_2 = f (\Sigma d_1 + \Sigma d_2)$. This leads to a very simple method of computation. Take the sum of the displacements in the direct and reverse measures and multiply by a factor which is a constant so long as the same regions are used and whose values are computed for all combinations of regions that are used. The product $= M_2$. This corrected for the velocity of the original Sun plate (V_0) gives the radial velocity of the star relative to the observer. The reduction to the Sun is made in the usual way.

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[1] HARTMANN uses a camera lens giving good focus over a long range of spectrum. In stars of later types he is able to measure a length of spectrum from λ 4[illegible] to λ 4[illegible]. In this extent of spectrum the change of dispersion is sufficient to make the above correction appreciable. It is negligible, however, when we are limited to a spectrum of only two or three hundred tenth-meters in length.

The great advantage claimed for the method, aside from those which it possesses in common with the velocity standard method, is that we are able to measure and reduce, in an hour or so, a plate of a star of a type rich in lines (several hundred on a plate) and practically utilize all the material on the plate. With the older methods to make such a measure and reduction utilizing all of the lines on the plate would require one or two days.

In Conclusion.—For the measure and reduction of spectrograms of stars of the earlier types, the use of the Cornu-Hartmann dispersion formula will suffice, in as much as the spectra of such stars consist of lines due to the simple gases, the wave-lengths of which have been accurately determined in the laboratory.

The measure and reduction of spectrograms of stars of the solar and later types will be accomplished with great saving of time and labor, and, moreover, by a method free from some of the uncertainties of wave-lengths by the use of the spectro-comparator. If the observer is not provided with such an instrument, the standard-velocity method would be used, in preference to any dispersion formula method, at least until a system of wave-lengths of the requisite accuracy is available.

For the case of later type stars it will be necessary to make corrections for the variation of lines with spectral type. It should be noted, however, that the corrections for some lines are positive while for others they are negative, so that the effects due to the variation of lines in stellar spectra of different types are to some extent compensating in radial velocity determinations.

Mt. Hamilton, Cal.

OPPORTUNITIES FOR SOLAR RESEARCH.[1]

By George E. Hale.

It is safe to say that every astronomer would prize an opportunity to observe any of the fixed stars from a position where its disk would appear as large as the Sun. It does not seem probable, however, that such observations of stellar phenomena can ever be made, except in the case of the Sun itself. For it should ever be borne in mind, when considering the importance of solar research, that our most intimate knowledge of stellar-phenomena must be derived from solar observations. In the case of the other stars, we may determine their positions, measure their radial velocities, observe their brightness, and analyze their light, but we have no means of studying the details of their structure, which must be understood before we can advance far in the solution of the great problem of stellar development. Thus we are driven back to the Sun, and forced to the conclusion that this typical star well deserves our most serious attention, and the application of every available means of research.

One cannot but be impressed, when considering the Sun from this standpoint, with the comparative neglect of the numerous opportunities awaiting the student of solar physics. It is possible, by the application of easily available instruments, for any careful student, wherever situated, to solve solar problems of great importance. If space permitted, it could be shown that almost all of the apparatus required in such work can be constructed at very small expense. For our present purpose, however, let us assume that the observer has at his disposal one of the cœlostats so commonly employed in eclipse work. If this cœlostat has a rather thick mirror, which is frequently resilvered, it may be depended upon to serve well for solar work, provided that the mirror is shielded from sunlight during the intervals between the exposure of photographs, and that these exposures are made as short as possible. We may assume that the sunlight is reflected from the cœlostat mirror to a second plane mirror (which should

[1] Read before the *Astronomical and Astrophysical* Society of America, New York, *December, 1906.*

also be as thick as possible) and from this mirror to an objective, which should have an aperture of at least six inches and a focal length of from forty to sixty feet. In place of this objective, a concave mirror, of similar aperture and focal length, may be employed. This apparatus will furnish the necessary means of forming a fixed solar image, of large diameter, within a laboratory, where accessory apparatus can be mounted. Let us now consider briefly some of the investigations that can be undertaken.

DIRECT PHOTOGRAPHY.

The routine photographic work, done under the direction of the Greenwich Observatory, provides ample material for the study of the positions and motions of sun-spots, but special investigations may well be undertaken with the aid of direct photographs. The important thing in all solar work is not merely to make observations of some single phenomenon, but to carry on two or three series of carefully correlated observations, so designed as to throw light on one another. For example, Mr. MAUNDER has recently found that the rotation periods of sun-spots in nearly the same latitude show differences as great as those encountered in passing from the equator to the highest latitude in which the spots are found. The cause of such differences may well be a subject of most careful investigation. The proper motions of spots, which are associated with their period of development, must be fully taken into account. We might also make the hypothesis, merely for the purpose of testing the question, that the rotation period of a sun-spot depends upon its level with respect to the photosphere. For this reason it would be desirable to investigate, in connection with the study of rotation, the question of the level of sun-spots. A simple means of doing this will be mentioned later. But it may be added here that the question of level raises other considerations, which should not be left out of account. It is probably worth while to investigate photographically the old Wilsonian hypothesis, since visual observations have proved so discordant in attempts to determine the relative widths of the preceding and following penumbra of spots at various distances from the center of the Sun. As a sun-spot is depressed below the level of the surrounding faculæ, the vexed question of the visibility of

the umbra near the limb may depend upon whether the faculæ are present or missing on the sides lying in the line of sight. It is quite possible that the temperature of the umbra may vary with its distance above the photosphere. Thus correlation between observations bearing on spot level and observations of spot spectra is desirable.

SPECTROSCOPY.

The spectroscopic study of solar phenomena has been greatly retarded through delay in adopting suitable instruments. The short-focus spectroscopes attached to equatorial telescopes are admirably adapted for visual observations, but in photography their linear dispersion is much too small to realize the full resolving power of the grating employed. In laboratory work, on the contrary, while the spectroscopes have been sufficiently powerful, they have usually been of the concave grating type, where astigmatism interferes seriously with the study of solar details, and the solar image on the slit of the spectroscope has been so small that the individual phenomena, in any event, could not be separately distinguished.

The preparation of a powerful spectrograph of the Littrow type is an extremely simple matter. A small slit, mounted on a short metallic tube, is supported immediately above a long narrow photographic plate. The wooden support for plate-holder and slit rests on a pier and forms the end of a long light tube of rectangular section, which is closed at its other end by the wooden support of the lens which serves at once for collimator and camera. The angular aperture of this lens is of course defined by that of the objective which forms the solar image on the slit, but if possible its focal length should be from ten to twenty feet. The rays, after being rendered parallel by the lens, fall upon a grating, which need not be larger than a four-inch (a much smaller one would do very useful work). The spectra should be photographed in the second, third, or fourth order, so as to give sufficient scale.

With such an instrument, new work of great value may be done. Even with a very small solar image, a photographic study of the solar rotation should yield results of great precision. HALM believes, from his spectroscopic work, that the rotation period varies with the solar activity. This is yet to be confirmed, but the question well deserves investigation

There is some reason to think that the rotation period is not the same for different substances in the reversing layer. The iron lines, for example, may give values different from those obtained with the carbon lines. It is also interesting to inquire whether the "enhanced" lines of an element give the same period as the other lines in its spectrum.

Another interesting investigation, which does not require a large solar image, is the study of the radial velocity of the calcium vapor in the flocculi. It is only necessary to measure, with great precision, the wave-lengths of the H_2 and H_3 lines, corresponding to various points on the solar image. In this way the rise or fall of the calcium vapor in the flocculi can be ascertained. To be of the most service, this investigation should be carried on in conjunction with some other study of the flocculi.

The photographic study of sun-spot spectra offers a most promising opportunity. It is a very easy matter to photograph spot spectra in such a way as to record for study thousands of lines which are beyond the reach of visual observations. Nevertheless, this has been accomplished only recently, simply because spectrographs of suitable design have not previously been applied in this work. At the Solar Observatory on Mt. Wilson it has been found that in general the lines strengthened in spot spectra are strengthened in the laboratory when the temperature of the vapor is reduced, while the lines that are weakened in sun-spots are weakened in the laboratory under the same conditions. Thus it appears probable that the temperature of the spot vapors is below that of the reversing layer. This conclusion has been confirmed by the discovery in the spot spectrum of the flutings of titanium oxide. This molecule thus exists at the lower temperature of the sun-spot, but is broken up at the higher temperature of the reversing layer. The bearing of this result upon stellar spectroscopy will be seen when it is remembered that the flutings of titanium oxide form the principal feature of the spectrum of the third-type stars. It has also been found that *Arcturus* gives a spectrum resembling very closely the spectrum of a sun spot. A further study of this question will require a large number of observations of spot spectra, with special reference to possible variations in temperature, as indicated by variations in the relative intensity of the spot lines. As already remarked,

the temperature of spots may also depend upon their level, and this possibility must be borne in mind.

WORK WITH THE SPECTROHELIOGRAPH

It is perhaps commonly supposed that the spectroheliograph is necessarily an expensive instrument, out of reach of the average observer. As a matter of fact, however, a spectroheliograph capable of giving the best results can easily be constructed of materials ordinarily available in any observatory or physical laboratory. It is sufficient, for many purposes, to photograph only a narrow zone of the solar image. In this case small lenses will suffice for the collimator and camera, and small prisms for the optical train. The lenses and prisms may be mounted in wooden supports, on a wooden platform, rolling on four steel balls in V-shaped tracks. The motion of the instrument across the solar image may easily be produced by a simple screw, driven by a small electric motor. Such a spectroheliograph was used to good purpose at the Solar Observatory before the permanent instrument was completed.

Brief mention may be made of some of the numerous investigations possible with such an instrument. It has recently been found at the Solar Observatory that the dark hydrogen flocculi, photographed near the Sun's limb, are slightly displaced with reference to the corresponding calcium flocculi. In general, they lie nearer the limb. This probably indicates that the absorbing hydrogen clouds are on the average at a higher level than the brilliant calcium clouds. This subject deserves careful investigation, extending over a considerable portion of time. The type of spectroheliograph just referred to is as suitable for the purpose as any instrument that can be constructed. Another question, which seems to be somewhat more difficult to solve, is the actual difference in elevation of the calcium flocculi, as photographed in the H_1 and H_2 lines. Indeed, it is still a question as to how important a part the dense calcium vapor plays in determining the form of the H_1 flocculi. These objects resemble the faculæ so closely that they appear practically identical with them, though slight differences, which are apparently genuine, are occasionally found.

Another method of investigating this whole question of levels is afforded by the spectroheliograph. It will be remem-

bered that when the level of sun-spots was last under discussion reference was made to the relative radiation of the umbra and neighboring photosphere, corresponding to different distances from the center of the Sun. It was pointed out that when the spot approaches the limb its radiation decreases less rapidly than that of the photosphere. The natural conclusion was that the spot lies at a higher level than the photosphere, and thereby escapes much of the absorption produced by a comparatively thin layer of absorbing matter. Recent observations at Mt. Wilson have shown, however, that the proportion of violet light in sun-spots is much smaller than in the case of the photosphere. As it is known that the violet rays undergo much more absorption near the Sun's limb than those of greater wave length, it is obvious that the light of the spot would suffer less absorption, even if it were at the same level as the photosphere. Thus the only proper method of investigating this question will be through the use of monochromatic light.

The spectroheliograph affords a simple means of accomplishing this. It is only necessary to make photographs of the spot and adjoining photosphere, corresponding to various distances from the Sun's center. The camera slit should be set on the continuous spectrum (not on a line), preferably in the violet or ultra-violet, since the change of absorption would be most felt in this region. In order to make photographic comparisons easily possible, the intensity of the photosphere should be reduced to approximately the intensity of the umbra, by means of a dark glass, mounted over the collimator slit, but not covering that part of the slit through which the light of the umbra passes. It is obvious that a large image of the Sun will be required in this work.

The spectroheliograph can be applied to other studies of absorption. The H_1 flocculi, for example, are reduced in brightness near the Sun's limb much more than the H_2 flocculi, presumably because the latter lie at a higher level. These differences can be studied photometrically on spectroheliograph plates made for the purpose. In the same way the H_1 flocculi can be compared with the faculæ. Since it is a question just what level is represented by the background (between the flocculi) in calcium, hydrogen, or iron photographs, the instrument should be arranged so as to permit photometric com-

parisons of this background with the photosphere, photographed with light from the continuous spectrum immediately adjoining the calcium, hydrogen, or iron line employed for the flocculi.

These new applications of the spectroheliograph have only recently occurred to me, and are mentioned because of their suitability for use with instruments containing prisms of ordinary height, capable of photographing only narrow zones of the solar image. Numerous other problems might be mentioned, such as the comparative study of H_1, H_2, and H_3 photographs, and of calcium, hydrogen, and iron images; the distribution of the flocculi in latitude and longitude; their varying area, as bearing on the solar activity and on terrestrial phenomena; and their motion in longitude, as measuring solar rotation. But limitations of time forbid more than a mere reference to work and methods the details of which are discussed elsewhere. My purpose has been accomplished if I have shown that with comparatively simple instrumental means any careful observer may secure important results. In much of this work it is desirable that investigators occupied with similar problems should co-operate with one another. The International Union for Co-operation in Solar Research was organized with this end in view. It has already inaugurated solar studies on a common plan in several different fields, and is preparing to extend the range of its activities in the near future.

NOTE ON THE DISTRIBUTION OF DOUBLE STARS IN THE ZONE $+56°$ TO $+90°$.[1]

By R. G. Aitken.

The main object of the survey of the sky that has been in progress at the Lick Observatory for the past seven years is to accumulate data for a statistical study of the number and the distribution in space of the double stars whose combined magnitude is brighter than 9.1 of the B. D. scale, and whose angular separation is less than $5''$. This survey is now well advanced toward completion, so far as the sky area

[1] Read before the Astronomical and Astrophysical Society of America, New York, December, 1906.

north of $-22°$ Declination is concerned, and it becomes a matter of interest to ascertain what kinds of data it is likely to yield.

In general, the various $4°$ zones into which the sky was divided for this survey have not yet been completely examined, the winter hours of Right Ascension, from 7^h to 14^h, being considerably less advanced than the remaining portion. But the entire area north of $+56°$ has been examined, and I have tabulated the results. Some of these tabulations and my conclusions based upon them I desire to present briefly.

The region named was divided into eight zones, of which Professor HUSSEY examined four,—namely, $+60°$ to $+64°$, $+64°$ to $+68°$, $+76°$ to $+80°$, $+80°$ to $+84°$, and the writer the remaining four. Professor HUSSEY included the 9.1 B. D. stars in his search, while I examined only those as bright as 9.0. In the following discussion only the stars to 9.0 are included.

As the area north of $+60°$ was almost entirely examined with the 12-inch telescope, while about one half of the zone, $+56°$ to $+60°$, was examined with the 36-inch, the latter is considered separately.

It has been the experience of both observers that, under good conditions, a double star with nearly equal components will be recognized with certainty with the 12-inch telescope if the distance is as great as $0''.25$; in fact, we have each discovered several pairs with that instrument whose distances, measured later with the 36 inch, were found to be well *under* $0''.25$. If the two components differ two or more magnitudes, we cannot be sure to detect the duplicity if the distance is much under $1''$. If the distance is $2''$ or more, a companion as faint as 13 or 13½ magnitude will be seen readily.

Since every previously known double star as bright as 9.0 magnitude was carefully identified in the course of the search, the fact that they were first seen with telescopes of very different apertures has no bearing upon the present discussion, so that the results given for the zone $+60°$ to $+90°$ may be considered to be based entirely upon the separating power of the 12-inch telescope.

By actual count of the stars on the charts used in the search, I find that in the region north of $+60°$ we have examined 12,209 stars of 9.0 magnitude or brighter. Of these, 294 were

known double stars, and 259 more were found to be double during our survey, giving a total of 553 pairs in this sky area. This includes seven bright stars with distances exceeding 5″, and excludes duplicates. That is, when we have found that one component of a Struve or other known pair is itself double only the closer pair is counted.

It appears, then, that one star in 22¼ in this region is a close double within the separating power of a good 12-inch telescope, a ratio somewhat smaller, as I have reason to believe, than will be found to hold for the sky in general. The tables that accompany this note exhibit the distribution of these pairs. Table I gives the number of new discoveries and the number of previously known double stars in each zone and for each six hours of Right Ascension. Table II combines the new and old pairs for each hour of Right Ascension for the whole region and for the two zones + 60° to + 68° and + 68° to + 90° separately.

TABLE I. + 60° TO + 90°.

QUADRANT I. 0^h TO 6^h.

Zone.	Double Stars. New.	Old.	Total.	Stars to 9.0 Mag.	Ratios. New D. S. to 9.0 Stars.	Ratios. D. Stars to 9.0 Stars.
84° to 90°	0	4	4	107	1 :	1 : 26.8
80 to 84	2	5	7	193	1 : 96.5	1 : 26.2
76 to 80	7	10	17	330	1 : 47.2	1 : 19.4
72 to 76	14	10	24	418	1 : 29.9	1 : 17.4
68 to 72	11	12	23	574	1 : 52.2	1 : 23.0
64 to 68	21	21	42	691	1 : 33.0	1 : 16.5
60 to 64	25	31	56	1041	1 : 41.6	1 : 18.6

QUADRANT II. 6^h TO 12^h.

Zone.	New.	Old.	Total.	Stars to 9.0 Mag.	New D. S. to 9.0 Stars.	D. Stars to 9.0 Stars.
84° to 90°	3	0	3	110	1 : 36.7	1 : 36.7
80 to 84	4	3	7	193	1 : 48.2	1 : 27.6
76 to 80	2	2	4	281	....	1 : 70.2
72 to 76	6	7	13	337	1 : 56.2	1 : 25.9
68 to 72	5	7	12	405	1 : 81.0	1 : 33.8
64 to 68	10	12	22	519	1 : 51.9	1 : 23.6
60 to 64	12	14	26	639	1 : 53.2	1 : 24.6

QUADRANT III. 12^h TO 18^h.

Zone.	New.	Old.	Total.	Stars to 9.0 Mag.	New D. S. to 9.0 Stars.	D. Stars to 9.0 Stars.
84° to 90°	1	3	4	130	1 :	1 : 32.2
80 to 84	2	5	7	191	1 : 95.5	1 : 27.3
76 to 80	5	3	8	288	1 : 57.6	1 : 36.0
72 to 76	5	4	9	372	1 : 74.4	1 : 41.1
68 to 72	10	7	17	461	1 : 46.1	1 : 27.1
64 to 68	12	6	18	545	1 : 45.4	1 : 30.3
60 to 64	12	11	23	610	1 : 50.8	1 : 26.5

QUADRANT IV. 18h TO 24h.

Zone.	Double Stars. New.	Old.	Total.	Stars to 9.0 Mag.	Ratios. New D. S. to 9.0 Stars.	Ratios. D. Stars to 9.0 Stars.
84° to 90°	2	2	4	117	1 : 58.5	1 : 29.2
80 to 84	3	7	10	219	1 : 73.0	1 : 21.9
76 to 80	9	6	15	328	1 : 36.4	1 : 21.9
72 to 76	15	12	27	412	1 : 27.5	1 : 15.3
68 to 72	14	16	30	587	1 : 41.9	1 : 19.6
64 to 68	21	21	42	965	1 : 46.0	1 : 23.0
60 to 64	26	53	79	1236	1 : 47.5	1 : 15.6

SUMMARY.

Quadrant I	80	93	173	3354	1 : 41.9	1 : 19.4
II	42	45	87	2484	1 : 59.1	1 : 28.6
III	47	39	86	2597	1 : 55.3	1 : 30.2
IV	90	117	207	3864	1 : 42.9	1 : 18.7
Total	259	294	553	12299	1 : 47.5	1 : 22.24

TABLE II.

RATIOS OF DOUBLE STARS TO STARS 9.0 OR BRIGHTER, BY HOURS OF R. A.

R. A.	Zone +60° to +90°.	Zone +68° to +90°.	Zone +60° to +68°.
0h	28 : 624 = 1 : 22.3	12 : 262 = 1 : 21.6	16 : 362 = 1 : 22.6
1	33 : 644 = 1 : 19.5	18 : 278 = 1 : 15.4	15 : 366 = 1 : 24.4
2	29 : 611 = 1 : 21.1	13 : 293 = 1 : 22.5	16 : 318 = 1 : 19.9
3	27 : 547 = 1 : 20.3	8 : 275 = 1 : 34.4	19 : 272 = 1 : 14.3
4	31 : 497 = 1 : 16.0	13 : 277 = 1 : 21.3	18 : 220 = 1 : 12.2
5	25 : 431 = 1 : 17.2	11 : 237 = 1 : 21.5	14 : 194 = 1 : 13.9
6	11 : 439 = 1 : 39.9	6 : 226 = 1 : 37.7	5 : 213 = 1 : 42.6
7	14 : 432 = 1 : 30.9	6 : 239 = 1 : 39.8	8 : 193 = 1 : 24.1
8	16 : 411 = 1 : 25.7	5 : 211 = 1 : 42.2	11 : 200 = 1 : 18.2
9	19 : 416 = 1 : 21.9	13 : 221 = 1 : 17.0	6 : 195 = 1 : 32.5
10	10 : 394 = 1 : 39.4	3 : 211 = 1 : 70.3	7 : 183 = 1 : 26.1
11	17 : 392 = 1 : 23.1	6 : 218 = 1 : 36.3	11 : 174 = 1 : 15.8
12	9 : 375 = 1 : 41.7	7 : 220 = 1 : 31.4	2 : 155 = 1 : 77.8
13	11 : 414 = 1 : 37.6	6 : 226 = 1 : 37.7	5 : 188 = 1 : 37.6
14	10 : 375 = 1 : 37.5	6 : 190 = 1 : 31.7	4 : 185 = 1 : 46.2
15	21 : 462 = 1 : 22.0	7 : 260 = 1 : 37.1	14 : 202 = 1 : 14.4
16	16 : 480 = 1 : 30.0	9 : 268 = 1 : 29.8	7 : 212 = 1 : 30.3
17	19 : 491 = 1 : 25.8	10 : 268 = 1 : 26.8	9 : 223 = 1 : 24.8
18	25 : 524 = 1 : 21.0	13 : 272 = 1 : 20.9	12 : 252 = 1 : 21.0
19	24 : 650 = 1 : 27.1	10 : 259 = 1 : 25.9	14 : 391 = 1 : 29.4
20	25 : 557 = 1 : 22.3	11 : 257 = 1 : 23.4	14 : 300 = 1 : 21.4
21	43 : 696 = 1 : 16.2	13 : 248 = 1 : 19.1	30 : 448 = 1 : 14.9
22	44 : 686 = 1 : 15.6	18 : 319 = 1 : 17.7	26 : 367 = 1 : 14.1
23	46 : 751 = 1 : 16.3	21 : 308 = 1 : 14.7	25 : 443 = 1 : 17.7

SUMMARY.

Quadrant.			
I	173 : 3354 = 1 : 19.4	75 : 1622 = 1 : 21.6	98 : 1732 = 1 : 17.7
II	87 : 2484 = 1 : 28.6	39 : 1326 = 1 : 34.0	48 : 1158 = 1 : 24.1
III	86 : 2597 = 1 : 30.2	45 : 1432 = 1 : 31.8	41 : 1165 = 1 : 28.4
IV	207 : 3864 = 1 : 18.7	86 : 1663 = 1 : 19.3	121 : 2201 = 1 : 18.2
Total	553 : 12299 = 1 : 22.24	245 : 6043 = 1 : 24.7	308 : 6256 = 1 : 20.3

It is at once apparent from these tables that the double-star distribution follows in a general way the distribution of all stars to 9.0 magnitude. and if the numbers in Table II are plotted the resemblance of the curves is striking.

But an unexpected feature of the distribution is the fact that the double stars are *relatively as well as absolutely more numerous in the richer sky areas,* the numbers in the four quadrants of Right Ascension being very nearly as 2 to 1 to 1 to 2.4 while the numbers of the stars to 9.0 magnitude are about as 1.3 to 1 to 1 to 1.5. When the zones + 60° to + 68° and + 68° to + 90° are taken separately the same relation is found in each.

My next effoft was to determine whether a different relation would be shown by the closer pairs or by the brighter pairs. The pairs under 2″ were separately tabulated, then those under 1″, then the very close pairs, ⅓″ or less, and finally the pairs as bright as 7.5 magnitude. It is not necessary to give the details, but the results by quadrants are as follows:—

	I. No.	I. Ratio.	II. No.	II. Ratio.	III. No.	III. Ratio.	IV. No.	IV. Ratio.
Under ⅓″	15	1 : 224	9	1 : 276	11	1 : 236	24	1 : 161
" 1	76	1 : 44	37	1 : 67	40	1 : 65	80	1 : 48
" 2	113	1 : 30	56	1 : 44	66	1 : 39	132	1 : 29
" 5	173	1 : 19	87	1 : 29	86	1 : 30	207	1 : 19
7.5 Mag. or brighter	49	1 : 68	23	1 : 108	18	1 : 144	63	1 : 61

It is clear from an inspection of this table that the closer pairs, which may safely be classed as binary systems, follow the same general law of distribution as do all the pairs here considered, and also that magnitude does not materially affect the question. In fact, I find that the average magnitude of the closer pairs in the second and third quadrants is slightly greater, numerically, than that of the corresponding pairs in the other two. So far as this factor goes, therefore, rather more difficult pairs were detected in the second and third quadrants than in the first and fourth. The result is not

affected by the time of year in which the work was done, as only nights of good seeing were used, and, besides, the search in each quadrant extended over from six to nine months.

It may therefore be accepted as a fact that in the sky area from + 60° to the North Pole, *double stars of all classes up to 5″ separation are relatively more numerous in the region richest in stars to 9.0 magnitude*,—that is, in the region of the Milky Way.

The zone + 56° to + 60° contains 4,257 stars as bright as 9.0 that were actually examined with the telescope. The fourth quadrant was almost wholly surveyed with the 12-inch, the first with the 36-inch, and the other two about in equal parts with the two telescopes. Of these stars 114 were known double stars and 130 more were found to be double, making a total of 244 pairs, or a ratio of 1 to 17.4. When the numbers of double stars and of stars to 9.0 in each hour of Right Ascension are plotted the two curves again show a very marked similarity.

Grouped by quadrants, we find the following relations:—

	Stars to 9.0.	Double stars.	Ratio.
I	1413	98	1 : 14.4
II	716	35	1 : 20.4
III	672	30	1 : 22.4
IV	1456	81	1 : 18.0

Thus in this zone, too, we find that the double stars are relatively more numerous in the regions richest in stars to 9.0 magnitude, though the curve is somewhat affected, as one would expect, by the fact that the fourth quadrant was examined with a much less powerful instrument than the other three, especially the first.

When the ratios are taken by zones of Declination, we find:—

Zone.	Ratio.	Zone.	Ratio.
+ 84° to + 90°	1 : 30.9	+ 68° to + 72°	1 : 24.7
+ 80 to + 84	1 : 25.7	+ 64 to + 68	1 : 21.9
+ 76 to + 80	1 : 27.9	+ 60 to + 64	1 : 19.2
+ 72 to + 76	1 : 21.1	+ 56 to + 60	1 : 17.4

The charts used in the survey give evidence of local irregularities in the distribution of the double stars, the ratio in some areas of 15 to 20 square degrees being as high as 1 to 7 or 8 and in others as low as 1 to 50. The study of these irregu-*larities is deferred* to the time when the whole northern

hemisphere shall have been examined, when a division of the sky into small sections of approximately equal area will make it possible to decide whether there is any marked tendency toward gregariousness on the part of the double stars and also whether, as a whole, they are distributed symmetrically relatively to some plane,—as, for instance, that of the Milky Way.

LICK OBSERVATORY, December 4, 1906.

ASTRONOMICAL OBSERVATIONS IN 1906.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

Z *Cygni*.[1]

Jan.	20:	Z = c.
Apr.	8:	invisible.
	14:	< e.
	22:	id.
May	24:	id.
July	26:	= b.
Aug.	19:	< a. > b′.
	24:	= b′.
	27:	id.
Aug.	31:	< b′. > b.
Sept.	8:	= b.
	19:	id.
	24:	id.
Nov.	10:	1 step > e.
	13:	1 step < e.
Dec.	4:	3 steps < e.
	9:	id.
	23:	invisible.

S *Ursæ Majoris*.[2]

Jan.	1:	S = g.
	19:	f′.
Feb.	28:	1 step < e.
Mar.	14:	= d.
	19:	id.
	29:	2 steps > d.
Apr.	2:	id.
	5:	4 steps > d. 9 steps < c.
	8:	6 steps > d.
	10:	id.
	12:	id.
	14:	4 steps < c.
	22:	id.
May	11:	= d.
May	23:	= e.
July	26:	invisible.
Aug.	19:	= g.
	24:	> g. < f.
Aug.	27:	id.
	31:	id.
Sept.	5:	1 step > f′.
	8:	< e. > f′.
	10:	id.
	12:	id.
	19:	id.
	21:	1 step < e.
	23:	id.

[1] Vide the *sketch in the Publications A. S. P.*, No. 100, p. 16.
[2] *Vide the sketch in the Publications A. S. P.*, No. 73, p. 56.

Sept. 24:	id.
27:	= e.
Oct. 11:	= d.
Nov. 10:	4 steps > d.
13:	id.
Dec. 4:	1 step > d.
9:	3 steps > d.
23:	= e.

T *Ursæ Majoris.*[1]

Jan. 1:	T = d.
19:	1 step > e.
Feb. 28:	invisible.
Mar. 14:	id.
19:	id.
29:	id.
Apr. 5:	id.
10:	id.
12:	id.
14:	id.
22:	id.
May 5:	id.
July 26:	$\begin{cases} < \text{a.} \\ > \text{b.} \end{cases}$
Aug. 19:	= b.
24:	id.
27:	$\begin{cases} < \text{a.} \\ > \text{b.} \end{cases}$
Aug. 31:	id.
Sept. 5:	= b.
8:	id.
10:	id.
12:	id.
19:	$\begin{cases} < \text{b.} \\ > \text{c.} \end{cases}$
21:	1 step > c.
23:	id.
24:	id.
27:	= c.
Oct. 11:	1 step < d.
Nov. 10:	= f.
13:	< g.
Dec. 4:	invisible.
9:	id.
23:	id.

W *Pegasi.*[2]

Jan. 1:	W 1 step > e.
2:	id.
19:	1 step > c.
July 26:	invisible.
Aug. 19:	< n*.
24:	id.
Sept. 19:	< h.
Oct. 11:	1 step < g.
Nov. 10:	= g.
13:	= f.
Dec. 4:	1 step > e.
9:	1 step < d.
10:	= d.
23:	2 steps > c.

* n is a star between W and b.

SS *Cygni.*[3]

P.M.	
Jan. 2, 6^h:	SS < g.
20, 6^h:	1 step < g.
Apr. 7, 14^h:	< d.
14, 9^h:	< f.
22, 9^h:	< d.
July 26, 11^h:	= e.
28, 10^h:	$\begin{cases} < \text{e.} \\ > \text{f.} \end{cases}$
Aug. 19, 10^h:	= g*.
Aug. 24, 10^h:	= e.
27, 10^h:	= c.
31, 10^h:	$\begin{cases} > \text{c.} \\ < \text{b.} \end{cases}$
Sept. 5, 10^h:	= c.
Sept. 8, 10^h:	= d.
11, 10^h:	1 step > e.
12, 9^h:	id.
19, 9^h:	< g.

* g is the faint companion-star next c towards East.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 22, p. 63.
[2] Vide the sketch in the *Publications A. S. P.*, No. 60, p. 23.
[3] Vide the sketch in the *Publications A. S. P.*, No. 100, p. 18.

Sept. 21,	9^h:	id.
24,	9^h:	= h.
Oct. 11,	9^h:	= g.
Nov. 10,	6^h:	id.
13,	6^h:	id.
Dec. 4,	6^h:	1 step < c.
6,	6^h:	= d.
9,	11^h:	= e.
11,	6^h:	id.
23,	6^h:	= g.

Y *Tauri* (B. D. + 20°.1083).

As comparison-stars I have used A = B. D. 20°.1095 ($7^m.4$) and b = B. D. + 20°.1073 ($8^m.2$). A third star, B = B. D. + 20°.1093 ($7^m.3$), I always find *smaller* than A.

Jan. 2:	> b.
19:	id.
Mar. 2:	> A.
14:	id.
19:	= A.
20:	> A.
29:	1 step > A.
Apr. 2:	id.
Apr. 5:	id.
12:	3 steps > A.
Sept. 27:	> A.
Nov. 13:	= A.
Dec. 4:	a little > b.
9:	< A. > b.
23:	id.

This irregular variable star seems to have had its greatest brightness about the spring and summer of 1906, while in the year 1905 its brightness had not reached that of the star A.

TV *Cygni*.

This star oscillates in brightness a little about $9^m.5$. I have compared it with the stars b and c in the sketch by A. STANLEY WILLIAMS (*A. N.* 3629) and always found TV < b.

Apr. 7,	14^h:	TV = c.
July 26,	11^h:	> c. < b.
Aug. 27,	10^h:	id.
Sept. 25,	12^h:	id.
Oct. 11,	9^h:	id.
Nov. 10,	6^h:	> c. < b.
13,	6^h:	id.
Dec. 4,	6^h:	= c.
23,	6^h:	> c. < b.

FIREBALLS.

In the past year thirty-one fireballs have been seen from stations in Denmark. The details of the five most interesting of these meteors are here given, as follows:—

No. 1. April 11, 9^h 28^m P.M. An exploding meteor lightens up the whole region and disappears 30^{km} above the mouth of Horsens Fjord. The path of the meteor went steeply downwards.—22 reports.

No. 2. June 24, 11^h 3^m. Gigantic fireball over northern Jutland, where a detonation like rumbling of thunder was heard. The meteor probably exploded above the island Laesö, in Kattegat, and the phenomenon was seen at several places

in Denmark, Norway, and Sweden. Some newspapers reported that fragments of this meteor had fallen down in the duckyard of the Göteborg, "Gibraltar," but unfortunately it was only a "newspaper duck"!—23 reports.

No. 3. July 26, 11^h 28^m. An exploding fireball with a great flashing light was seen from Odder in the east, leaving a 5°-long train; duration 30^s.—7 reports.

No. 4. November 23, 2^h 45^m. A large fireball was seen from several places in Jutland, in spite of the dazzling sunshine, as a sparkling exploding meteor, leaving an extensive train for a moment; 30^{km} west from Horsens the meteor passed the zenith and over this region a loud detonation like thunder-roaring was heard. Some thought of a powder explosion; people ran out of the houses, thinking an earthquake had taken place; horses ran frightened about in the fields. The fireball exploded 60^{km} above the ground, and, according to its direction, this meteor may be noted as a "salutation from the Bielids," which were expected at that time.—12 reports.

No. 5. December 18, 6^h 10^m. A flashing and exploding fireball was seen from Jutland in the southeast, not far from *Saturn*, as observed at Odder. Its train was straight for a minute, but in the next minute it was turning and winding. —10 reports.

Shooting-Stars.

In the period August 9th-12th corresponding observations were arranged for from seven stations in Denmark. The weather was not favorable, and our efforts succeeded only on August 12th. At these stations 122 paths of shooting-stars were mapped, but only six proved suitable for calculation. These six meteors have given the following results:—

For Observation.

No.	Time.	Station.	Beginning.	Ending.	Mag.	Observer.
1	Aug. 12, 10^h 14^m 0^s P.M.	Odder	....	316°.4 + 9°	2	T. Köhl.
		Nyborg	....	310 + 15	2	Ch. Fros
2	Aug. 12, 10 21 45 P.M.	Odder	359° + 22°.8	353 + 13	4	T. Köhl.
		Nyborg	20 + 44	6 + 30 .3	2	Ch. Fros
3	Aug. 12, 10 27 33 P.M.	Odder	....	292 + 30	2	T. Köhl.
		Nyborg	....	255 .5 + 57	2	Ch. Fros
4	Aug. 12, 10 36 30 P.M.	Odder	40 + 40 .8	40 + 33	1	T. Köhl.
		Nyborg	56 .5 + 47	59 + 41 .2	2	Ch. Fros
5	Aug. 12, 10 56 30 P.M.	Askov	50 .8 + 37 .2	54 .2 + 31 .7	♀	L. Dolle
		Odder	47 + 40 .5	50 + 35	♀	T. Köhl.
		Nyborg	61 .8 + 46	71 + 42 .6	♃	Ch. Fros
6	Aug. 12, 11 4 40 P.M.	Odder	....	351 + 23	1	T. Köhl.
		Nyborg	....	15 + 61 .3	1	Ch. Fros

For Calculation.

No.	Beginning.			Ending.			Real Length of the Path.	Radiant.	
	h	λ	φ	h	λ	φ	β	AR	Decl.
1	....	......	....	51.9	1° 26′.6 w	54° 56′.4	....	....	
2	95.1	0° 1′.4 e	55° 50′.1	102.4	0 32.0 e	55 26.4	55.6	153°	+22°.1
3	....	......	....	119.0	2 26.4 w	55 27.1	....	....	
4	152.5	1 36.6 e	57 29.2	92.6	1 5.4 e	57 5.1	82.4	40.2	+66.6
5 AO	166.0	2 6.0 e	57 43.9	82.2	0 39.0 e	57 8.7	139.0	40.3	+49.9
5 AN	164.5	2 4.3 e	57 43.6	82.3	0 41.5 e	57 10.2	133.0	39.5	+50.3
5 ON	163.0	2 2.0 e	57 42.5	82.2	0 39.7 e	57 9.1	132.8	39.8	+50.3
6	....	......	....	83.1	1 3.2 w	55 39.3	....	....	

h and *β* are expressed in kilometers; λ is longitude from Copenhagen; *φ* is north latitude; *h* is the altitude of the meteor above the Earth's surface.

ERRATA.

In the *Publications A. S. P.*, No. 89, p. 66, for *T U* read *R T* in the sketch as also in the text.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	Mar. 7,	$12^h 42^m$ A.M.	Last Quarter..	Apr. 5,	$7^h 20^m$ A.M.
New Moon...	" 13,	10 5 P.M.	New Moon...	" 12,	11 6 A.M.
First Quarter.	" 21,	5 10 P.M.	First Quarter.	" 20,	12 38 P.M.
Full Moon...	" 29,	11 44 A.M.	Full Moon....	" 27,	10 5 P.M.

The Sun passes the vernal equinox and spring begins about 10 A.M., Pacific time, March 21st.

Mercury is an evening star at the beginning of March, setting about an hour and one half after sunset, and will be

an easy object for a few days about that date on clear evenings. It comes to greatest east elongation on March 1st, 18° 10′. This is a much smaller greatest elongation than the average, as it comes less than three days after perihelion. The planet approaches the Sun quite rapidly after the first few days of the month, passing inferior conjunction on the night of March 17-18th and becoming a morning star. It then moves rapidly away from the Sun, reaching greatest west elongation on April 14th. Its apparent distance from the Sun will then be 27° 36′, which is fifty per cent greater than its distance at the time of greatest east elongation in March; but the conditions for visibility are not nearly as good, as *Mercury* is now 13° south of the Sun, and rises less than an hour before sunrise, so that it will be impossible to see it with the naked eye.

Venus is still a morning star, rising 2^h 20^m before sunrise on March 1st, 1^h 38^m on April 1st, and 1^h 20^m on April 30th. The planet passed greatest west elongation on February 8th, and is now nearing the Sun, but the main cause of the diminution of the interval between the rising of the planet and of the Sun is the southward motion of the planet relative to the Sun. *Venus* passes about 1° 39′ north of the vernal equinox on the afternoon of April 26th. At 7 A.M. April 21st, Pacific time, it is in very close conjunction with *Saturn*, passing 0° 38′ north of the latter.

Mars rises at 1^h 36^m A.M. on March 1st, at 12^h 50^m A.M. on April 1st, and at 11^h 52^m P.M. on April 30th. During the two-months period it moves 31° eastward and 2° southward, from *Scorpio* through the southern extremity of *Ophiuchus* into *Sagittarius*, and during the latter part of April is in the neighborhood of the "milk-dipper" group in the latter constellation, a little farther north. Its distance from the Earth diminishes from 121 millions of miles on March 1st to 70 millions on April 30th, and its brightness at the latter date is consequently about three times as great as it was at the former, rather more than a magnitude, as the brightness of stars is usually reckoned. From now on it will be a conspicuous object until some months after opposition.

Jupiter is in fine position for evening observation. On March 1st it sets a little before 3 A.M. and on April 30th at a little before 11:30 P.M. It is in the constellation *Gemini*,

and moves about 7° nearly due eastward during the two months. It is in a region richer in bright stars than any other in the sky. *Castor and Pollux* are east of the planet, *Aldebaran* is west, and the bright stars of the *Orion* group, with *Canis major* and *Canis minor*, are to the south

Saturn is an evening star on March 1st, but sets about half an hour after sunset, and is therefore too near the Sun for naked-eye observations. On the night of March 8-9th it passes conjunction with the Sun and becomes a morning star. The planet does not reach a great enough distance from the Sun to be seen in the morning twilight until well into April. At the end of the month it rises about an hour and three quarters before sunrise. It is in the constellation *Pisces*, and moves about 6° east and 3° north during the two months.

The phenomena displayed by *Saturn's* rings during 1907 will be of great interest to astronomers. The rings are so nearly edgewise to the Earth throughout the year that very little can be seen of them with a small telescope, but large telescopes may be able to show some new and interesting things. Since the autumn of 1891 both Sun and Earth have been above the plane of the rings, but on April 12th the Earth passes through this plane and from that time until July 25th the Earth and Sun are on opposite sides of the plane and the face turned toward us is the unilluminated face. On July 25th the plane of the rings passes through the Sun, and until October 4th both Sun and Earth are on the same side of the plane On October 4th the Earth again passes through the plane, and for the remainder of the year the Earth and Sun are again on opposite sides. Early in 1908 the Earth again passes through the plane, and for the succeeding fifteen years the Earth and Sun are both below the plane Questions as to the transparency and thickness of the rings may possibly be solved The year 1907 affords the best opportunity for the study of these phenomena which we have had for many years. *Saturn* is in opposition in September, and the planet is fairly well placed for observation from the middle of April to the end of the year. In 1891 Sun and Earth were on opposite sides of the ring for only one month, and this period began only ten days after conjunction, so that the planet was too near the Sun for satisfactory observation.

Uranus rises shortly before 4 A.M. on March 1st and shortly

before midnight on April 30th. It is still in *Sagittarius* north of the "milk-dipper."

Neptune is in *Gemini*, a few degrees east of *Jupiter*.

THE CAUSE OF EARTHQUAKES AND MOUNTAIN FORMATION.[1]

By T. J. J. See

Soon after the great earthquake of April 18th, the writer entered upon a general examination of the cause of earthquakes, because the explanations put forth to account for that phenomenon seemed inadequate. The conclusions finally reached have been embodied in a memoir just published in the *Proceedings* of the American Philosophical Society at Philadelphia; they had also been given in a public address at Leland Stanford Jr. University, on November 15th. The principal results are the following:—

(1) Volcanic activity, earthquakes, mountain formation, the feeble attraction of mountains noted in geodesy, the formation of plateaus and islands, and the great sea-waves which frequently accompany violent earthquakes, are all due to one common cause,—namely, the development of steam within or just beneath the Earth's crust, chiefly by the secular leakage of the ocean-bottoms, which are subjected to fluid pressure of nearly one thousand atmospheres by the superincumbent depth of water.

(2) As the development of steam is general under the seas, the strain under the Earth's crust would find relief chiefly around the margins of the oceans. The Pacific Ocean not only has high mountains all around it, but the land is rising geologically, and seven eighths of the active volcanoes of the world surround this great ocean. No active volcano is over about one hundred miles from the ocean or other large body of water, while many are submarine, and volcanic islands are forming all the time. Of the vapors emitted by volcanoes 999 in 1000 parts is steam, which again confirms the dependence

[1] Abstract of a lecture delivered before the A. S. P. in Hearst Hall, University of California, November 24, 1906.

on the sea inferred from the remarkable geographical distribution of these vents.

(3) Heretofore the mountains have been explained by the contraction and secular cooling of the Earth; but the explanation is very inadequate. Rev. O. FISHER has shown that the actual mountains are about one hundred times higher than this theory will account for, and this discrepancy can only indicate the unsoundness of the theory. In his paper on the rigidity of the heavenly bodies (*A. N.* 4104) the writer has shown that no currents circulate within the Earth, either now or at any time since the formation of the crust; the cooling has therefore been confined to the crust, and the secular shrinkage has been wholly insensible throughout all geological time. The mountains therefore have been formed by the sea, and not by the secular cooling of the Earth. This explains why the mountain chains are generally parallel to the seashore

(4) Mountains, plateaus, and islands have all been upheaved by the injection of steam-saturated lava, which dries and becomes pumice, some of which is blown out of those mountains which become volcanoes. The mountains are underlaid with pumice, and hence their feeble attraction noticed in geodesy. Earthquakes are more general than volcanoes, which break out where the elevation of the land opens an outlet through the crust, as a rule, the volcanoes are near the centers of the earthquake belts, and always near the sea. In most world-shaking earthquakes lava is pushed under the land, from beneath the sea, hence the terrible shaking which is so destructive to life and property. In South America the land along the seacoast is frequently upraised; and a seismic sea-wave follows.

(5) The seismic sea-wave is due to the sinking of the sea-bottom, after its support has been weakened by the expulsion of lava under the adjacent coast. Hence after the earthquake the water drains away to fill up the depression, the currents meet in the center and raise a ridge, and when this collapses the great wave returns to the shore to add to the horrors of the earthquake The Andes are pushed up along the coast, while the adjacent sea-bottom is sunk down into a trough. If the earthquake uplifts the coast, and thus forms mountains along the seashore, while the wave is due to the collapse of the sea-bottom, it is clear that the coast is being packed underneath

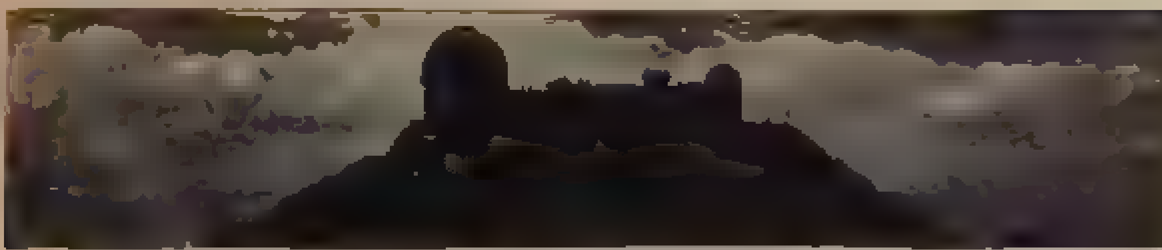
with lava, while the bed of the sea is being undermined by the expulsion of material to raise the mountains.

(6) During the great earthquake in Alaska, September 3-20, 1899, which has been most carefully investigated by Professor R. S. Tarr and Lawrence Martin,[1] the uplift of the land at the maximum amounted to 47⅓ feet, while elevations of seven to twenty feet were common, though slight depressions also occurred in a few places. Professor H. D. Curtis, of the D. O. Mills expedition of the Lick Observatory, reports from Santiago[2] that the harbor at Valparaiso was found to be ten feet shallower after the earthquake of August 16th. These observations give the key to the problem of earthquakes and mountain formation. The indications of nature are plain enough, if we will only follow her teachings and examine the evidence on its merits. The first duty of the investigator is to study for himself; important truth is not discovered without impartial judgment, labor, and thought.

The reader is referred to the paper in the *Proceedings* of the American Philosophical Society for further details of the complicated processes arising in earthquakes, mountain formation, and kindred phenomena.

Naval Observatory, Mare Island, Cal.,
February 1, 1907.

[1] *Bulletin of the Geological Society of America*, May, 1906.
[2] Cf. *Argonaut* of November 2, 1906.



NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on Mt. Hamilton Weather.

The Lick Observatory is now passing through the most severe snow blockade that it has experienced at least since 1889-90. Between January 12th and 16th the snowfall exceeded fifty inches. The latter part of the fall was attended by considerable wind, and long stretches of the road were drifted full. The snowfall was remarkable for the low altitude to which it descended. At Smith Creek it amounted to eighteen inches, and the fall extended down to within one hundred or two hundred feet of the level of the Santa Clara Valley. No stage has reached the summit since January 12th, and at the date of writing, January 22d, we are not expecting the stage to come to the summit for another week at least. The wires which gave us telephone connection with the outside world were broken down under the great weight of snow and ice which collected on them. On two days we did not attempt to communicate with the stage, which ascended as far as Smith Creek. On other days the mails and supplies were carried up over the snow by members of the staff. Fortunately, no illness developed, and the inconvenience of the blockade has thus far not been serious.

The winter has been unusually cold, stormy, and cloudy. The precipitation to date corresponds to about twenty-one inches of rainfall.

W. W. Campbell.

On the Relation between Stellar Spectral Types and the Intensities of Certain Lines in the Spectra[1]

During the past summer, in connection with the measurement of spectrograms obtained at the Mills Observatory in Chile by Professor Wright, an investigation of the individual spectrum lines was begun, with a view of determining whether

[1] A more complete account of this investigation is published in *Lick Observatory Bulletin* No. 106, and in *Astrophysical Journal*, Vol. 24, p. 333, 1906.

there is a shift of any of the lines which is progressive from spectral type to type. Several lines were found which undergo such a progressive change, as is indicated by the radial velocities obtained from them. An examination of ROWLAND's tables shows that in most but not all cases studied lines apparently single are in reality blends of two or more close components. The nature of the variations found is such as to indicate varying intensities of the same components rather than the presence or absence of different components in the different types. It was the intention, when sufficient data had been obtained, to make comparisons with the enhanced and weakened lines in the spark and arc spectra. When a list of sun-spot lines[1] in the region covered by the Southern Mills plates became available, a comparison with these was made instead. The investigation was limited to stars of types F to Mb inclusive on the Harvard classification. In this classification the Sun is of type G.

The principal result of the comparison is the very strong indication that the physical conditions in the stars as we pass from the F to the Mb type vary in the same direction as from the Sun to the sun-spots. It is not intended to convey the impression, however, that any one type has been found in which the conditions are exactly the same as in the sun-spots, though an early K type is probably nearest to it. In the Mb type the relative intensities of the lines as shown, both by their appearance and their residuals, have gone far beyond what they are in the Sun, whereas in the F type they much precede the condition in the solar spectrum. ADAMS has shown a striking similarity to exist in the intensities of sun-spot lines and of the corresponding lines in the spectrum of *Arcturus* (type K), while HALE and ADAMS[2] have made a similar comparison of intensities for α *Orionis* (type Ma) in the region λ 5393 to λ 5703.

A large number of lines might be mentioned which change greatly in intensity and appearance as we proceed from the F to the Mb type, this change being frequently very prominent even from the G to the K type, and which are not included in ADAMS's list of lines affected in sun-spots. Among the most

[1] "Sun-spot Lines in the Spectrum of *Arcturus*," by WALTER S. ADAMS, *Astrophysical Journal*, Vol. 24, p. 69, 1906.

[2] *Astrophysical Journal*, Vol. 23, p. 400, 1906.

striking of these are the Cr lines, λ 4254.5 and λ 4274.9, which become very strong, wide, and diffuse as we follow the scale of stellar types. A few cases of contradictory evidence have also been found, in which the residuals show a decided shift in the opposite direction from that which would be expected from the intensities assigned to the components in sun-spots. Among these the line λ 4435.2 may be especially mentioned. For this blend both my value of the wave-length, as determined from the spectrograms, and the progressive trend of the residuals indicate a shift of its center toward the violet instead of toward the red. Some of the observed differences between sun-spots and stellar K type, in which the physical conditions may be similar, may be due to the fact that in the stars this condition is the average condition in their entire atmospheres, while in the case of the sun-spots some effects may be altered by overlying layers of gases and vapors or by other local circumstances. Nevertheless the similarities are sufficiently striking to promise much for this line of study. The results here given depend not only upon the appearances of the lines, but primarily upon quantitative measurements of their positions.

It was thought possible that for variable stars of large light changes traces of velocity variations of some of the lines might be found, corresponding to small changes in spectral type as the stars varied from maxima to minima and *vice versa*. In the case of *o Ceti* actual changes in the character of the spectrum are well-established facts, though up to the present no appreciable changes in the wave-lengths of any of its spectrum lines have been observed—leaving out of account the large displacements of the bright hydrogen lines. A comparison of the available measures of η *Aquilæ*, a variable star of the fourth class with a range of only 0.8 of a magnitude in light variation, showed evidences of variations in the positions of some of its lines from light maximum to minimum similar to the variations that were found from type to type. A further study of this variable star is desirable to establish definitely the exact character and amount of these variations.

The following few examples are typical of the progressive variations that were found for the different types. The intensities in the Sun are Rowland's, and those in sun-spots and in *Arcturus* are taken from Adams's article (*l. c.*).

λ 4352.908 Fe—Intensity in Sun, 4 } In sun-spots, 6-7; in *Arcturus*, 7-8;
53.044 V —Intensity in Sun, 0 } widened toward red.

Residuals (in km.):—

F	F8G and F8G Pec.	G	G5K	K	K	K2M and K5M	Mb
−3.0	−3.7	+0.8	−0.7	+1.6	+2.1	+3.6	+3.4
	+1.5	+1.0	−0.6	+3.1	+3.4	+3.0	+4.9
	−1.0	+1.7	+2.2	+0.8	+2.6	+3.0	+4.6
	+1.5	−1.1	+2.8	+1.4	+1.4	+1.0	+4.7
	−3.5		±0.0	+2.6	+4.8	+3.9	+3.9
			+1.7	+3.1	+2.2	+2.2	+6.5
				+1.5	+0.8	+4.4	
				+2.2	−0.2	+3.3	
				+0.8	+4.3	+3.0	
				+2.0	+1.9		
				+0.9	+3.2		
					+3.6		
Means:							
.....	−1.0	+0.8		+2.2		+3.0	+4.7

λ 4468.663 Ti—Intensity in Sun, 5; in sun-spots, 4-5; in *Arcturus*, not affected.

Residuals:—

F	F8G	G	G5K	K	K	K5M	Mb
−1.3	−2.2	−0.3	+1.4	+2.8	+2.7	+5.7	+6.8
−4.1	−0.3	−1.5	+0.9	+2.6	+3.7	+0.8	+7.0
+1.7	−2.9	−0.9	−0.7	+3.9	+4.3	+6.3	+3.5
−3.0	−0.9		−0.9	+1.1	+1.5	+2.5	+6.1
−3.7	+1.4		+2.7	+1.0	−0.3	+4.7	+4.8
			−2.1	+0.6	+1.9	+4.7	+1.9
				+2.2	+0.6	+4.7	+1.7
				+0.4	+0.4	+5.2	+5.9
				−0.4	−1.5		
				+1.2	−3.0		
				+1.3	+3.3		
				+0.7	−0.1		
Means:							
−2.1	−1.0	−0.9	+0.2	+1.3		+4.3	+4.7

λ 4314.964 Ti—Intensity in Sun, 1 }
15.138 Ti—Intensity in Sun, 3 } Not included in list of sun-spot lines.
15.262 Fe—Intensity in Sun, 4 }

Residuals:—

	F	G	K	K5M	Mb
Means:	+1.1	−1.4	−2.0	−2.7	−5.0

λ 4435.129 Ca—Intensity in Sun, 5; in sun-spots, 6 }
.32 Fe—Intensity in Sun, 2; in sun-spots, not affected. } In *Arcturus*, 8.

Residuals:—

	F	F8G and G	G5K and K	K5M	Mb
Means:	−4.0	−1.7	+0.3	+2.5 ±	+1.8 ±

The establishing of these variations in the wave-lengths of some of the lines with spectral type will make necessary the exercise of great care in the selection of lines in radial velocity determinations, and a proper allowance for the type.

Mt. Hamilton, December 14, 1906. SEBASTIAN ALBRECHT.

Honors Conferred upon Professors Aitken and Hussey.

The Paris Academy of Sciences has conferred the Lalande Prize for 1906 upon Professor R. G. Aitken, of the Lick Observatory, and Professor W. J. Hussey, formerly of the Lick Observatory, and now Director of the Detroit Observatory at Ann Arbor. The prize usually consists of a gold medal and a small sum of money. It has on several occasions been divided between two astronomers, as in the present case.

The following paragraphs are translated from the report of the award published in *Comptes Rendus* for December 17, 1906:—

"No branch of sidereal astronomy presents to-day a higher interest than that relating to the study of double or multiple stars.

"Among contemporary astronomers who have undertaken this study with success, Messrs. R. G. Aitken and William J. Hussey,[1] astronomers in the Lick Observatory, are in the first rank, because they have each discovered more than 1,200 new doubles;[2] and in almost three fourths of these pairs the distance of the components is less than two seconds of arc.

"These astronomers have, moreover, measured with care all these pairs in such a manner as to fix the present relative positions of the components.

"In addition, they have made observations upon the fainter satellites of *Jupiter, Saturn,* etc.

"These are results of the highest importance, and the Commission proposes to divide the Lalande Prize between Messrs. R. G. Aitken and W. J. Hussey.

"The conclusions of this report are adopted by the Academy."

W. W. Campbell.

Mt. Hamilton, January 22, 1907.

[1] Professor Hussey has recently left the Lick Observatory, in order to become Director of the Detroit Observatory of the University of Michigan.—*Comptes Rendus.*

[2] The number 1,200 refers necessarily to those published. Professor Aitken, up to 1907, has discovered more than 1,500 double stars, and Professor Hussey had discovered more than 1,300 up to the time of his departure in June, 1905.—W. W. C.

The Orbit of Ho 212 = 13 *Ceti*.[1]

In number 104 of these *Publications* a note on this interesting binary system will be found giving my measures in 1905, which indicated a revolution period of about 7½ years. Measures made in 1906 confirm this conclusion, the companion-star being now within a few degrees of the position it occupied in 1899.

Using Dr. See's measure in 1899 and my own made in the following years (the only ones known to me), I have derived the set of elements here given. They satisfy the observations on which they were based within the probable error of measure, and also satisfy the two early measures by Hough in 1886 and 1887.

It is now certain that 13 *Ceti* has a shorter period than any other known visual binary except δ *Equulei*. A well-defined proper motion adds to the interest of the system.

ELEMENTS.

$P = 7.42$ years.	$\omega = 51^\circ.75$
$T = 1905.28$	$\Omega = 50\ .40$
$e = 0.74$	$i = \pm\ 48^\circ.05$
$a = 0''.214$	Angles increasing.

January 24, 1907. R. G. Aitken.

Note on Comet *h* 1906 (Metcalf).

This comet was discovered near opposition by Rev. J. H. Metcalf, of Taunton, Mass., from a photograph taken November 14, 1906. The discovery position is $\alpha = 4^h\ 4^m\ 35^s$, $\delta = -2^\circ\ 15'.8$.

No preliminary elements were computed here for either this comet or Comet Thiele, which was discovered at about the same time, as the observatory force was crippled by the illness of Mr. Einarson, Assistant in Astronomy, so that no time was available for computing.

Later, however, two sets of elements based upon longer arcs were derived, and the results have been published in *Lick Observatory Bulletin* No. 108. The first set is based upon Fath's observations of November 17th, 25th, and December 5th. It was found that no parabola could be passed through

[1] A more detailed account is given in *Lick Observatory Bulletin*, No. 110.

these positions. They are represented, however, by an elliptic orbit in which the comet has a period of 6.9 years.

An observation by Dr. AITKEN, made December 18th, is not very closely represented by these elements. It was therefore decided to correct them by means of this observation. The resulting second set is also elliptic, giving a period of 8.2 years. The plane of the orbit is inclined nearly 15° to the plane of the ecliptic. The comet made its nearest approach to the Sun, 150 millions miles, October 5th. It is a new member of *Jupiter's* family of comets.

At the time of discovery it was very faint and was receding from both the Earth and the Sun. At present it can be seen in only the largest telescopes, its brilliancy being less than one fourth of what it was at discovery.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT,
January 18, 1907.

GENERAL NOTES.

Stellar Photometry.—Publication No. 33 of the Carnegie Institution of Washington, "Researches in Stellar Photometry," by JOHN A. PARKHURST, Instructor in Practical Astronomy in the University of Chicago, was issued during November of the year just closed. The quarto volume of 192 pages contains observations and discussions of twelve variable stars of long period observed by Mr. PARKHURST between 1893 and 1905 During the first seven years the observations were made mostly at Marengo. Illinois, with a 6-inch Newtonian reflector by BRASHEAR. Since 1900 Mr. PARKHURST has been connected with the Yerkes Observatory, and the 12- and 40-inch refractors of that institution were used in addition to the 6-inch reflector. During the first period the observations were made visually by the method of ARGELANDER, but during the second period a wedge photometer, devised by Professor E. C PICKERING, was used for the most part.

In the introduction the author states that his work is addressed to the solution of four problems in photometry, and the statement of these is admirably prefaced as follows:—

"The problems of stellar photometry are closely connected with many cosmic questions, primarily with the light changes of variable stars; but they have an equally important bearing on the questions of stellar distribution and evolution It has been said by good authorities that it is of more importance to measure the light than the place of a star, and if one considers merely the astonishing number of variable stars now being discovered, it will be admitted that the importance of stellar photometry can scarcely be overestimated The material here submitted is the natural outgrowth of the writer's variable-star work, the plans being extended as the instrumental and other facilities were improved.

"The following contribution is offered toward the solution of several photometric problems, among them being:—

"(1) The accurate determination of complete light-curves of twelve variable stars of long period, having faint minima.

"(2) The question of behavior of variable stars during their faint stages which can only be observed with the largest apertures

"(3) The adaptation of the Pickering 'equalizing wedge photometer' to the determinations of magnitudes

"(4) The photometric measurement of very faint magnitudes, and their relation to estimates founded on the limit of visibility of different *apertures of telescopes*"

Under the headings "Essentials for good visual comparisons" and "Essentials for good photometer measures," Mr. PARKHURST gives also in the introduction some very wholesome advice which it would be well for all variable-star observers to read.

Chapter I is devoted to a description of the instruments used, and especially to the consideration of the constants of the equalizing wedge photometer.

The following twelve chapters are devoted one each to the twelve variable stars observed,—T *Andromedæ*, V *Andromedæ*, W *Andromedæ*, R *Comæ*, RU *Herculis*, RV *Herculis*, S *Lyræ*, S *Cygni*, SX *Cygni*, V *Delphini*, Z *Cassiopeiæ*, Y *Cassiopeiæ*. These are for the most part new variables discovered during the last decade of the nineteenth century. Each chapter contains a short historical statement; a photograph of the field of the variable made with a 24-inch reflector; various tables giving the individual observations, the comparison-stars, constants for reduction, observed maxima and minima, etc.; the magnitude-curve; the light-curve; the mean light-curve; and conclusions giving period of star and peculiarities of its light-curve. The observations and reductions have been made with minute care and great thoroughness, and it is evident from the tests applied that the results obtained by Mr PARKHURST are possessed of a high degree of precision.

The magnitudes of the stars observed lie between 7.5 and 17, the greatest range of any one variable, V *Delphini*, being nine magnitudes, from 8 to 17, a really remarkable range. The only other variable having an observed range of more than 7.5 magnitudes being χ *Cygni*, 4.5 to 13.5. The average range for the twelve stars is 5.8 magnitudes. The periods of these lie between 259 and 529 days, the average being 362 days. A large number of long-period variables have periods approximately a year in length, and the average period is over three hundred days and apparently approaching closer to a year. It seems hardly likely, however, that these facts have any special significance.

It is well known that in stars of this class the increase in light is accomplished in less time than the decrease, the ratio between the two parts of the period being about five to six. This feature is well shown in the light-curves of all the twelve stars observed by PARKHURST, except S *Cygni*, for which

M — m is almost exactly one half the period. The inequality between increase and decrease of light is greatest for V *Delphini*, the ratio being about five to eight. Its period is 529 days, one of the longest known. This star shows, then, three distinctive characteristics among the twelve stars, its period is the longest, its range is the greatest, and the inequality between the two parts of the period is the largest.

The elements obtained by the author for the twelve stars are derived from observations of ninety-five maxima and ninety-three minima. The observations, however, were not confined to the epochs of maxima and minima, but were carried on, as far as possible, over the whole period, and the special feature of the volume is the well-determined mean light-curves which have been derived in each case. It is now generally recognized among variable-star investigators that it is just as essential to determine the *form* of the light-curve as to determine the length of the period. Several good series of variable-star observations from which light-curves may be deduced have been published without graphic representation of the curves, and the usefulness of the investigations considerably decreased thereby.

In the concluding chapter there is given, among other things, a comparison between the theoretical and the observed limits of vision of the three telescopes employed in the investigations. The theoretical limits were computed by the use of Pogson's well-known formula and the agreements are remarkably close. The seventeenth magnitude is the limit of the giant 40-inch refractor.

It is to be hoped that Mr. Parkhurst may be able to continue in this line of work, for investigations such as these, planned with care, executed with skill, discussed with precision, are most urgently needed in variable star astronomy.

S. D. T.

Double-Star Orbits.—By his long-continued devotion to the study of double stars and by the quality of the many orbits he has published, Dr. W. Doberck has well earned his position as one of the leading authorities in this branch of astronomy. That his interest does not diminish with the years is evident from the number of his investigations that have recently appeared. The latest (*Astronomische Nachrichten*, *4144-4145*) are new orbits of three of the best known of the

binary systems,—namely, *ζ Cancri, ω Leonis,* and Σ 3062 = H I 39.

There are other recent orbits of all three of these systems that represent the observed motion up to the present time with a high degree of accuracy, and it is perhaps questionable whether so much labor as is represented by these new discussions was wisely bestowed. Nevertheless it is always interesting and instructive to compare the results obtained by different computors, using different methods of solution, especially when, as in the case of the three stars named, the orbits are based substantially on the same material. The periods of the three systems, according to DOBERCK, are 116, 105, and 60 years respectively, and the motion is not specially rapid at the present time in any one of them. The new elements of *ω Leonis* and Σ 3062 do not differ materially from the other recent orbits, and only serve as additional evidence that our knowledge of the motions in these systems is now fairly accurate.

In the case of *ζ Cancri,* Dr. DOBERCK'S results differ more from SEELIGER'S than might be expected, in view of the fact that the latter represent recent observations within the probable error of measure.

The two sets of elements are as follows:—

	P.	T.	*e*	*a*	ω	Ω	*i*
SEELIGER:	59y.11	1868.11	0.381	0″.858	250°.26	80°.19	11°.14
DOBERCK:	60 .08	1870.65	0.339	0 .856	183 .65	.....[1]	0 .00
	Angles decreasing.						

If one might venture any criticism upon such painstaking work as Dr. DOBERCK'S, it would be on the ground that he does not make much use of the measures of distance, basing his results almost exclusively upon the angle measures. The question might also be raised whether elaborate least-squares solutions are justified by the quality of the material available, but this question will be answered in due time by the way in which the results thus derived represent the future motions in these systems. A.

On Star Streaming.—At a meeting of the British Association for the Advancement of Science held at Cape Town, South Africa, August 17, 1905, Professor J. C. KAPTEYN read a paper with the above title. It cointained an announcement of

[1] The *planes of the true and of the apparent* orbit coincide in this solution.

the results of a study of the proper motions of over 2,400 stars observed by BRADLEY.

The study was taken up for the information it was expected to yield regarding the motion of the Sun among the stars, but certain anomalies appeared which seemed to indicate the existence of an important and hitherto unsuspected systematic motion among the stars under investigation. It appeared that the proper motions showed a trend toward two points in the sky about 140° apart, lying south of α *Orionis* and η *Sagittarii* respectively.

The explanation offered is that a large number of stars distributed throughout all of the regions of the sky covered by the Bradley catalogue partake of a common, or group, motion peculiar to themselves. All of the stars under investigation seemed to belong to one or the other of two groups.

This introduces a complication into the problem of determining the apex and velocity of the Sun's way, and Professor KAPTEYN desires confirmation from spectroscopic observations before proceeding to the completion of his study.

A subsequent study by Mr. A. S. EDDINGTON of the proper motions of the stars contained in the Groombridge catalogue has quantitatively confirmed Professor KAPTEYN'S conclusion. The 4,500 stars of the Groombridge catalogue include a much larger proportion of faint stars than the Bradley list, and they lie within a smaller area of the sky, all being within 52° of the North Pole. Mr. EDDINGTON concludes that the two-drift hypothesis is a good first approximation to the actual state of affairs, but he is by no means convinced that there may not be other drifts involving a sufficiently large number of stars, and so distributed that account will have to be taken of them in the solution of the problem of determining the Sun's motion among the stars. An abstract of Mr. EDDINGTON'S paper may be found in *Observatory* No. 377. N.

Algol Variable RR Draconis.—In *Bulletin* No. 9 of the Laws Observatory of the University of Missouri Professor SEARES presents the results of photometric observations of an interesting new variable of the *Algol* type, RR *Draconis*. The period is found to be 2.831079 days. At normal brightness the variable is of the tenth magnitude, and the decrease in brightness at the time of minimum is over three magnitudes. The

exact amount of decrease could not be determined with the telescope employed, for the star was invisible for a period of about two hours in the neighborhood of the minimum. The time occupied in the light changes is about ten hours. The rate of change of light at the steepest part of the curve is over a magnitude in half an hour.

This star at minimum is fainter than any other *Algol* variable listed in the Harvard Provisional Catalogue of Variable Stars. Its range of brightness is also greater than that of any other variable of this type, the average range being 1.4 magnitudes.

S. D. T.

National Academy of Sciences.—The autumn meeting of the National Academy of Sciences was held November 20th, 21st, and 22d in the buildings of the Harvard Medical School, Boston. Among the large number of papers presented five were upon astronomical subjects, as follows: "The Work of the Bruce Telescope," by S. I. BAILEY, of Harvard University; "Present State of Knowledge as to Motions of the Terrestrial Pole," by S. C. CHANDLER, Editor of the *Astronomical Journal*; "Extent and Structure of the Stellar System," by G. C. COMSTOCK, of the University of Wisconsin; "Sun-Spot Spectra, and Their Bearing on Stellar Evolution," by G. E. HALE, of the Solar Observatory of the Carnegie Institution; "Planetary Inversion and the Tenth Satellite of *Saturn*," by W. H. PICKERING, of Harvard University.

At the *conversazione* held in connection with the meeting, photographs, slides, and drawings were presented by the Harvard College Observatory and by the Solar Observatory of the Carnegie Institution.

The following notes have been taken from recent numbers of *Science*:—

Professor CHARLES LANE POOR, of Columbia University, gave a public lecture under the auspices of the New York Academy of Sciences and the American Museum of Natural History, on November 19th, on "The Proposed New Astronomical Observatory and Nautical Museum for New York City."

Dr. WILLIAM H. BROOKS, Director of Smith Observatory and Professor of Astronomy at Hobert College, Geneva, N. Y.,

has received a medal from the Astronomical Society of Mexico for his discoveries of twenty-five comets.

Professor RAJNA, of Bologna, is making an appeal for funds to rebuild the observatory there on a new site, and to provide it with instruments suited to modern requirements.

Professor ERNEST W. BROWN, who goes at the end of the present academic year from Haverford College to Yale University, has been awarded the gold medal for 1907 by the Royal Astronomical Society for his work on the movements of the Moon.

Mr. SYDNEY S. HOUGH, chief assistant in the Royal Observatory, Cape of Good Hope, has been appointed His Majesty's Astronomer at that observatory on the retirement of Sir DAVID GILL.

Dr. SIDNEY DEAN TOWNLEY, astronomer in charge of the International Latitude Observatory at Ukiah, California, and lecturer in astronomy in the University of California, has been appointed to an assistant professorship in the department of applied mathematics at Leland Stanford Junior University. Dr. TOWNLEY will assume the duties of his new position with the beginning of the next academic year in August.

NEW PUBLICATIONS.

ANDOYER, A. Cours d'astronomie. Première partie: Astronomie théorique. Paris: Hermann. 1906.

GIBBS, J. W. The scientific papers of. New York: Longmans, Green & Co. 1906. 2 vols., royal 8vo.

HILL, G. W. The collected mathematical works of. 3 vols. Washington: Carnegie Institution. 1906. $2.50 per vol.

LOWELL, P. *Mars* and its canals. New York: Macmillan Co. 1906. 8vo. 15 + 393 pp. Cloth, $2.50.

MORSE, E. L. *Mars* and its mystery. Boston: Little, Brown & Co., 1906. 8vo. viii + 192 pp. Cloth, $2.00.

MOULTON, F. R. An introduction to astronomy. New York: Macmillan Co. 1906. 8vo. 18 + 557 pp. Cloth, $1.25.

MOULTON, F. R. A class of periodic solutions of the problem of three bodies with applications to the lunar theory. Reprint from Trans. Am. Math. Society. 1906. 40 pp.

NEWCOMB, S. A compendium of spherical astronomy. New York: Macmillan Co. 1906. 8vo. 18 + 444 pp. Cloth, $3.00.

Optical convention, 1905: Catalogue of optical and general scientific instruments. Edinburgh: F. & E. Murray. 1906.

PARKHURST, J. A. Researches in stellar photometry. Washington: Carnegie Institution (Publ. No. 33). 1906. 4to. 192 pp. Paper, $2.00.

Science Year Book, The. Diary, directory, biography, and scientific summary for 1907. London: 27 Chauncy Lane. 1906. 5s.

SEARES, F. H. The *Algol* variable RR *Draconis*. Columbia: University of Missouri. (Laws Observatory Bulletin No. 9.) 4to. 15 pp.

VERSCHAFFEL, M. L'ABBÉ. Observations faites au cercle méridien en 1904. Abbadia: Observations. Tome IV. 4to. 190–.

Athens: Annales de l'observatoire national. Tome IV. 1906.

Transactions of the international union for co-operation in solar research. Vol. I. London: Sherratt & Hughes. 1906. 8vo. xii + 257 pp. Cloth.

Minutes of the Meeting of the Board of Directors held at the Students' Observatory, Berkeley, on January 26, 1907, at 7:30 p. m.

President Leuschner presided. A quorum was present. The minutes of the last meeting were approved.

The following new members were duly elected:—

List of Members Elected January 26, 1907.

Mr. Charles H. Crossland.............8 Forsythe St., Chelsea, Mass.
Mr. Curtis H. Thomas................Traer, Iowa.

It was upon motion,

Resolved, That the Committee on Publication be authorized to reprint number 2 of the *Publications* in an edition of 250 copies.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific held at the Students' Observatory at Berkeley on January 26, 1907, at 8 p. m.

President Leuschner called the meeting to order, and introduced the lecturer of the evening, Professor W. W. Campbell, Director of the Lick Observatory, who read his paper on "The Solar Corona," illustrating his remarks by a number of lantern-slides.

A committee to nominate a list of eleven Directors and Committee on Publication, of three members, to be voted for at the Annual Meeting to be held on March 30, 1907, was appointed as follows: Messrs. J. K. Moffitt (Chairman), S. D. Townley, C. D. Perrine, J. D. Galloway, O. von Geldern.

A committee to audit the accounts of the Treasurer and to report at the Annual Meeting in March, was appointed as follows: Messrs. Chas. S. Cushing (Chairman), Daniel Suter, B. A. Baird.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. A. O. Leuschner .... *President*
Mr. Chas. S. Cushing .... *First Vice-President*
Mr. A. H. Babcock .... *Second Vice-President*
Mr. W. W. Campbell .... *Third Vice-President*
Mr. R. G. Aitken, }
Mr. F. R. Ziel, } .... *Secretaries*
Mr. F. R. Ziel .... *Treasurer*

Board of Directors—Messrs. Aitken, Babcock, Burckhalter, Campbell, Crocker, Cushing, Hale, Leuschner, Richardson, Spreckels, Ziel.

Finance Committee—Messrs. Cushing, Crocker, Richardson.

Committee on Publication—Messrs. Aitken, Townley, Newkirk.

Library Committee—Mr. von Geldern, Mr. Richardson, Mrs. Schaid.

Committee on the Comet Medal—Messrs. Campbell (ex officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 806 Franklin Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof-sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes of addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific, 806 Franklin Street, San Francisco," in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY
(February, April, June, August, October, December.)

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, APRIL 10, 1907. No. 113.

PRELIMINARY STATISTICS ON THE ECCENTRICITIES OF COMET ORBITS.[1]

BY A. O. LEUSCHNER.

Various investigations of the eccentricities of the orbits of comets have led to the conclusion that the majority of such orbits are parabolic. In fact, about three fourths of all comet orbits have been found consistent with an eccentricity equal to unity. This is the main reason why it is generally accepted that a comet orbit is parabolic, unless it can be shown to be otherwise.

An accurate knowledge of the eccentricities of comet orbits is of importance in determining the origin of comets. It is, therefore, advisable to study the eccentricities from as many points of view as possible. Two methods of classifying the eccentricities have occurred to me which do not seem to have entered into the analysis hitherto. Both are related to the accuracy of the observational material from which the orbits are derived. One is to classify the eccentricities on the basis of the general accuracy of the observations, the other on the basis of the observed heliocentric arc.

Marked progress has been made during the last century in the methods of observation and in the construction of telescopes, so that observations have become more and more reliable, and the number of days during which comets of the same brightness may be followed has constantly increased.

Ever since the first computation of a comet orbit was made, it has been customary to derive a parabola as a first approximation to the orbit, and to attempt a more general solution only if the deviations of the observed positions from the places com-

[1] Abstract of address of the retiring President of the Society, presented at the annual *meeting, March 30, 1907.*

puted from the most probable parabola were in excess of the probable errors of observation. This custom has become so thoroughly fixed in astronomy that even now it would be considered absolutely unwarranted to suspect a comet of moving in an ellipse if by a little stretching of the probable limits of observational error a parabola could be found to represent the observed positions.

A prejudice has always existed, and exists now, in favor of the parabola. This prejudice is not entirely due to statistical investigations of the orbits of past comets. A further excuse for the same may be found in the fact that the first geometrical and analytical methods for solving a comet orbit were parabolic. The solution of an elliptic orbit was originally possible only in cases like HALLEY'S comet, where more than one appearance had been observed, so that one of the unknowns, the period, became known.

GAUSS'S general solution had its first application on the asteroid *Ceres*, at the dawn of the nineteenth century, and it was not until some time later that general methods were also applied to comets.

It is a well-recognized fact that when the observed arc is short and the probable error of observation on a comet is large, the solution of the orbit will be uncertain, or, in other words, in such cases a large number of different orbits will be found to satisfy the observations. The "Short Method" which has been used extensively in the Berkeley Astronomical Department during the last three years is well suited for estimating the limiting values of the elements. The range of possible periods and eccentricities is far greater than has perhaps been supposed hitherto. A cursory examination of many definitive orbits based on normal places formed from long series of observations shows that in many cases a long-period ellipse will often answer as well as a parabola. The ellipse is then generally dismissed with the statement that there is no reason to suspect a deviation from the parabola. It would be just as consistent to conclude that there is no reason to suspect that the comet moves exactly in a parabola. In accordance with existing belief regarding the eccentricities of comet orbits, Dr. KREUTZ in his biennial reports to the Astronomische Gesellschaft adopts the parabola whenever it is found sufficient.

Before proceeding to an examination of the published lists

of elements it is therefore well to emphasize that possibly in no case where an ellipse or hyperbola alone is given can the observations be represented by a parabola, but when a parabola is given the observations may frequently be consistent with an ellipse and sometimes with a hyperbola.

If, in spite of this fact, it can be demonstrated that by far the majority of well-determined orbits is elliptic, then the time has come when astronomers should abandon their prejudice for the parabola, by investigating and stating the complete range of possible solutions in each case.

OLBER'S, GALLE'S, and WINLOCK'S lists were not available when a preliminary examination of the eccentricities was undertaken. The excellent list, however, contained in E. WEISS'S edition of "Littrow, Wunder des Himmels," is well suited for the purpose of the preliminary investigation, especially because it gives the duration of visibility in days. This list runs to 1885. The results of the preliminary examination were, however, roughly revised just before publication on the basis of GALLE'S and WINLOCK'S lists and KREUTZ'S biennial reports to the Astronomische Gesellschaft to 1904, which latter are contained in the *Vierteljahrsschrift*. Comets discovered between 1885 and 1895 were added to WEISS'S list only when the duration of visibility was included in the data at hand. Periodic comets are, of course, counted only for their first apparition.

For the purpose of classifying the orbits on the basis of the general accuracy of the observational material, or more nearly of the observed positions, the percentage of parabolic orbits was ascertained for each of three groups, in the order of time as given in Table I.

TABLE I.

Dates.	$e = 1$
–1755	99 per cent
1756–1845	74 per cent
1846–1895	54 per cent

It is safe to assume that there has been a progressive and pronounced advance in the accuracy of observation in these three periods of time. Hyperbolic orbits were not included in the totals on which the percentages of Tables I and II are based. From the more accurate observations of the fifty years from 1846 to 1895 we may therefore conclude that it is no more probable that a *comet is* parabolic than that it is not.

In Table II the eccentricities have been grouped on the basis of the duration of visibility in days. The percentage of parabolas is given for each group. The comets discovered before 1756 have been excluded in the totals from which these percentages were derived, as their orbits can throw little light on the question under consideration.

TABLE II.

Duration of Visibility.	$e = 1$
1– 99 days	68 per cent
100–239 days	55 per cent
240–511 days	13 per cent

These figures are certainly striking. They show that the longer a comet is under observation the more probable it becomes that its orbit cannot be satisfied by a parabola.

This result is in entire accordance with the opinion held by some astronomers that few, if any, orbits are strictly parabolic. In the last group only eight comets were available, which are all given as elliptic by WEISS, and for one of these KREUTZ'S later reports give a parabola, which has been adopted, the same as every orbit has been considered parabolic in these tables for which the observations could be satisfied by a parabola. It is therefore extremely doubtful whether a parabola is definitely established for any comet having remained visible 240 days or more. It would have been better if Table II could have been based on the length of the observed heliocentric arcs, but these are not immediately available, and in a first approximation for a large number of comets the average of the number of days of visibility may be taken to correspond to the average heliocentric arc.

Percentages have also been derived for various ranges of eccentricity. These, however, will not be published until the final investigation has been concluded.

The average eccentricity of periodic orbits is very high. In applying the short method it has been found that whenever a short arc yielded a considerable range of periodic solutions, a longer arc would yield solutions for the eccentricity nearer the upper than the lower previous limits. The explanation of the high eccentricities lies in the nature of things. Long-period comets cannot come within the range of visibility *from* the Earth unless their orbits are highly eccentric. The

others must remain invisible, until the power of our telescopes is still further increased.

From the average brightness of comets at unit geocentric distance the maximum perihelion distance at which a comet may be seen in opposition from the Earth with the more powerful instruments may be derived. The values of the eccentricity corresponding to this maximum for a given value of the semi-major axis or period will then be the minimum eccentricity which the orbit of a comet of average brightness and of given period must have in order to be visible from the Earth, under the most favorable circumstances.

This question will be studied in connection with a proposed further study of comet orbits. The theory that, in general, comets are permanent members of our solar system seems to have been greatly strengthened by the foregoing preliminary statistics. It will be remembered that until KEELER began photographing nebulæ with the Crossley reflector the spiral was considered the exceptional form of a nebula. The percentage of double stars is increasing so rapidly that their discovery either directly, or spectroscopically, or photometrically, or otherwise, is no longer a cause for surprise. It seems eminently probable that with further investigation of cometary orbits the parabola will be found to be the exception.

BERKELEY ASTRONOMICAL DEPARTMENT, March 30, 1907.

THE SOLAR CORONA.[1]

BY W. W. CAMPBELL.

Of all the wonders of this and other worlds that it has been my good fortune to see, a total solar eclipse is by far the most impressive, and the Sun's corona is its central and most beautiful feature. The corona appears to have attracted the attention of intelligent observers who dwelt within the shadow-paths, in all ages of our civilization. PLUTARCH has left an excellent description of its appearance, and occasional later

[1] Lecture delivered *before the Astronomical* Society of the Pacific on January 28, *1907. The lantern slide illustrations* are necessarily omitted.

writers have referred to it. Speculation as to what the corona really is was naturally very meager prior to the middle of the last century, for the custom of dispatching expeditions to study eclipse phenomena had not been inaugurated, and it therefore seldom fell to the lot of any one man to observe two eclipses, either with or without scientific instruments and methods.

In KEPLER'S day, and until less than a century ago, the corona was believed by most men of science to be due to the illumination of the Moon's atmosphere. When it was finally established that the Moon has extremely little or no atmosphere, the corona was generally explained as a phenomenon of the Earth's atmosphere; and it was not until the year 1870 that the tide of scientific opinion turned toward the Sun itself as the origin and center of the corona. Even as late as 1883, one of the ablest of astronomical physicists published an admirable discussion of the corona as a purely subjective, non-material phenomenon, due to the diffraction of the Sun's photospheric rays at the Moon's edge. The objective existence and solar character of the corona are to-day thoroughly established, and the erroneous views of our predecessors come as a surprise no doubt to many persons of the younger generation. It is far otherwise with those who are familiar with eclipse history. Take away the spectroscopic method of study, which came nominally in 1859, but virtually, for eclipse purposes, later in the sixties, and take away the photographic plate which was made to bear upon the problem, faintly in the early seventies and strongly in the eighties,—take these away, and I think we should still be struggling with the question, Where is the corona situated? Let two of us make a pencil drawing of the same corona,—one of us in Spain and the other in Egypt. The two drawings will be more remarkable for their differences than for their agreements; and what is more natural than to attribute these differences to varying conditions in the terrestrial atmosphere above the two observers, or to the changed influence of the irregularities on the Moon's edge as viewed from the two points of observation. Let the eclipse observer of to-day try to find out something new about the corona, *even with* the spectroscope, polariscope, thermoscope, and photographic plate, and his respect for the pioneers will be established upon a firm basis.

The corona remains a strictly eclipse phenomenon. The

commendable efforts of several leading astronomers to observe the corona in full sunlight have unfortunately failed, on account of its relative faintness and its low effective temperature, and all the methods now available seem hopelessly unpromising. Given suitable appliances, such as the 40-foot eclipse camera designed by Professor SCHAEBERLE, the corona may be seen faintly and imperfectly during one to three minutes before totality is complete, and during an equal interval after totality ends; but we have not been able to make any scientific use of these pre- and post-totality views. Every item in our knowledge of the corona has been obtained during the total phase. Assuming that observable total eclipses occur, on the average, once in two years, and that their average duration is three minutes, no astronomer, in fifty years of activity in following the Sun and Moon, can hope to utilize more than seventy-five minutes in eclipse observation. Making the reasonable deduction of one third for clouds and other deterring factors, his maximum expectation during a long life must not exceed fifty minutes. The total duration of observable eclipses for any one observer since the spectroscope and photographic plate have been available scarcely equals a half-hour. Herein lies the chief difficulty of coronal investigation. However, the progress made since the spectroscope showed a bright coronal line, in 1869, and photographic plates at two stations showed identical coronal structures, in 1871, has been so great as to be unique in science.

Another difficulty in coronal study is for the most part only vaguely appreciated. The coronal streamers are on the whole radial, with reference to the Sun, and appear to overlie every part of the Sun's spherical surface. Now, every coronal structure lying within the cylinder occulted by the Moon is entirely hidden from view, and all structure lying outside of this cylinder is seen in projection upon one plane. The projected image of the corona recorded on the photographic plate is complex to an apparently hopeless degree. Every small area in the apparent inner corona is a composite of all the structures lying betwen the observer and the area in question. The tops of streamers pointing nearly toward and nearly away from the observer, the intermediate parts of numerous other streamers, and the bases of streamers nearly at right-angles to the *observer's line of sight* are all projected upon a common

area And similarly for all parts of the coronal image. There is no known way of resolving the composite image into its elements.

Notwithstanding these and other difficulties, we know much concerning the properties and characteristics of the corona. However, this knowledge has not reached the deductive stage. Our facts are isolated ones We are not only not able to predict the detailed form of a future corona, but we cannot say why an observed corona has a certain general form. We know so little concerning the origin of the corona and its dependence upon the rest of the Sun, that starting *de novo* with our present-day knowledge of the main body of the Sun, and no knowledge whatever of the corona, we should be more surprised by the existence of a corona than by its total absence!

Taking up first the study of coronal images, it has been established that there is a dependence of coronal forms upon the sun-spot period. At and near sun-spot maximum the general outline of the corona is circular The polar streamers are as extensive and as brilliant as the equatorial streamers That this is true of the outer regions of the corona as well as of the inner is shown by both long and short photographic exposures. At or near sun-spot minimum the general form is very different. The polar streamers are short, faint, delicate, and few. The equatorial streamers, and especially those in the sun-spot zones or at slightly higher latitudes, are longer than at maximum, and in general there are two broad streamers extending easterly and two westerly from the Sun, several solar diameters in length. These are necessarily but the projections of two sets of long streamers entirely encircling the Sun Their bases seem to be situated a little further from the equator than are the sun-spot zones. These variations in coronal forms with spot activity are now so well established that coronal streamers and spots may safely be said to have a closely related origin.

The hooded forms of the inner corona, each covering a conspicuous prominence, can leave no doubt that they and the prominences concerned have had a closely related origin

The great conical disturbance in the corona of 1901, noted by Dr. Perrine, whose vertex was shown by him to be situated immediately over or very near to the great and only spot on the Sun at the time, can leave little doubt that the disturbed

coronal structure and the photospheric disturbance indicated by the spot had a common origin.

All the evidence is to the effect that the corona is closely related to the rest of the Sun. We do not know the nature of this relation; but we can safely say that a thorough understanding of the Sun requires an understanding of the corona.

The light radiated by the corona appears to be of three kinds:—

1st. A thin and very irregular stratum, perhaps never exceeding 200,000 miles, and more probably never exceeding 100,000 miles, in depth, lying at the base of the corona and apparently resting upon the chromosphere, gives a bright-line spectrum. The natural interpretation of this spectrum is that the stratum giving rise to it consists of a gas or vapor heated to incandescence; but it has been suggested here and there that the bright lines may indicate an electric glow in the inner corona, such as one gets from a Plücker tube agitated by an electric current. For my part, there seems to be no real necessity for going beyond simple incandescence produced by the Sun's heat. The element yielding the ten or twelve bright lines[1] has not been identified with any terrestrial substance. There may indeed be more than one vapor or gas present.

It is difficult to conceive how irregular masses of vapor can maintain themselves at great heights above the solar surface, in opposition to the Sun's gravitational attraction. Perhaps the vapor is constantly given off by the solid or liquid particles which seem to form the major part of the inner corona, for these particles must be at a high temperature, under the influence of the Sun's heat.

2d. Nearly all of the light from the inner corona—perhaps ninety-five per cent of it—appears to give a strictly continuous spectrum, which indicates a solid or liquid source raised to incandescence. The most reasonable conclusion is that the inner corona consists largely of minute particles maintained at a very high temperature by the adjacent body of the Sun.

3d. The light of the middle and outer corona yields a spectrum which seems to be substantially identical with the solar spectrum—a spectrum containing the usual Fraunhofer dark lines. On this point there is not unanimity of observers. PLUVINEL in 1893 and the Crocker Expedition of 1901 to

[1] *DYSON gives a list of twenty-four corona lines.—Phil. Trans.*, Vol. 206, p. 451, 1906.

Sumatra and of 1905 to Spain have recorded dark lines, whereas others appear to have observed continuous spectrum, pure and simple. The discordance is difficult to explain. If the dark lines exist, we have every reason to believe that the corresponding parts of the corona consist of minute particles of matter, not shining appreciably by their own light, but principally by virtue of original sunlight which radiates to the particles and is reflected and diffracted to us.

The latter view is supported overwhelmingly by a long series of polarization observations. Granted that the corona is composed of minute particles which diffuse the sunlight falling upon them, the coronal light should be polarized, radially, very much as sunlight diffused by our own atmosphere is polarized strongly in planes passing through the Sun. It is true that polarization may be produced otherwise than by reflection or diffusion,—for example, by a magnetic field, as in the Zeeman effect; but polarization seems to exist in all parts of the corona.

The opinions of astronomers as to the materials composing the corona, and as to why the Sun has any corona at all, have been very divergent. Some have believed that the corona is composed of meteors, many of them revolving around the Sun, and others falling into the Sun. However, this theory is largely in disfavor, and we need not consider it, though no doubt there are a great many meteors both revolving around and falling into the Sun.

SCHAEBERLE'S mechanical theory proposes that "the theoretical corona is caused by light emitted and reflected from streams of matter ejected from the Sun by forces which in general act along lines normal to the surface of the Sun, these forces being most active near the center of each sun-spot zone." To account for the longer streamers in the corona, considering their materials to be ejected by forces analogous to volcanic forces and to be drawn back by the Sun's gravitational power, would require that their speeds on leaving the Sun should be between 200 and 400 miles per second. According to this theory, also, there would be multitudes of both ascending and descending particles.

According to BIGELOW'S magnetic theory, the corona is a sort of solar aurora whose streamers occupy positions corresponding to the lines of force in the Sun's magnetic field, just as the Earth's magnetic field seems to control the streamers of terrestrial auroras.

When LEBEDEW, and NICHOLS and HULL, some five or six years ago, proved experimentally that light and heat radiations exert a pressure upon all bodies in their paths, it occurred to ARRHENIUS, and possibly to others, that here is the basis for a satisfactory theory of the corona. If strong radiations press upon exceedingly minute particles, the particles will move away from the source of radiation; the larger and denser particles, speaking popularly, will travel slowly, and the lighter and smaller particles rapidly. There can be little doubt that matter exists at the Sun's surface in a state capable of being acted upon effectively by this radiation pressure. According to this theory, the smaller and lighter particles (more exactly, those having the smallest product of mass and density) would be driven off into distant space, with little chance of returning to the Sun; and the reuniting of two or more particles would in many cases give gravity the advantage, so as to bring them back to the Sun. It is true that this theory, in common with all the others, leaves much to be explained. For example, it is difficult to say why sun-spot inactivity should produce extraordinarily long streamers in the high sun-spot latitudes, and sun-spot activity streamers of equal lengths all over the Sun.

I think there is an excellent chance that all these theories have much truth in them. There can be no question that eruptive forces, or convection and evection currents of great speed, exist at the Sun's surface,—responsible for many of the prominences, certainly,—and perhaps they give an outward impulse to the coronal material. The forms of many coronal streamers certainly resemble closely the lines of force in a magnetic field, and we cannot doubt that radiation pressure must be active and effective. But it is scarcely conceivable that the eruptive forces on the Sun can give speeds of 300 or 400 miles per second to the ejected coronal materials, and the radiation-pressure theory renders the supposition of such great speeds unnecessary.

At the eclipse of 1900, ABBOT made one of the most important of recent eclipse observations, in that he measured the heat radiation of the inner corona. He found that the corona is effectively cooler than the instrument with which he observed. The observation was a delicate one and liable to considerable error. Although confirmation is very urgently desired, ABBOT's observation is probably approximately cor-

rect. ABBOT concluded that the corona appears "neither to reflect much light from the Sun nor chiefly by virtue of a high temperature to give light of its own, but seems rather to be giving light in a manner not associated with a high temperature. . . ." This conclusion seemed at first to deny the theory of the corona's constitution outlined above, as based upon the evidence of the spectroscope and polariscope; but a very illuminating paper by ARRHENIUS has, I think, shown that ABBOT's results on the heat of the corona are in harmony with the view that the inner corona consists mainly of incandescent particles.

ARRHENIUS has determined from computation that coronal particles in the region observed by ABBOT must have a temperature of about 4,300° C. (8,000° F.), assuming the effective temperature of the Sun's photosphere to be 6,000° C.; and, therefore, these particles must be radiating light by virtue of their own incandescence. These particles are so few and so far apart that the effective temperature observed by the bolometer is not at all the temperature of the particles themselves, but is, so to speak, the average temperature for the incandescent particles and the cold background of space upon which these particles are seen here and there in projection. The total area of the background covered by the particles in projection is an exceedingly minute fraction of the whole area. The spectroscopic and thermometric observations are harmonized within the limits of error of observation by assuming that, in the part of the corona observed, there is but one minute dust-particle for each fifteen cubic yards of space.

We should not overlook the fact that the series of incandescent points in the distant corona affect the eye or the photographic plate just as if they formed a continuous and highly illuminated surface, whereas the thermometer in effect averages the radiations from the coronal particles to the instrument and the radiations from the instrument to the cold background of space. The action of our atmosphere in stopping a certain proportion of the heat radiations is also effective and has to be taken into account.

The existence of matter in the corona at great distances from the Sun implies that it has come from somewhere—doubtless from the Sun itself. This necessarily implies that *motion has occurred*. Is the material of the corona moving

out from the Sun or toward the Sun, or both, or neither? We have no accurate observational knowledge on this subject. The unusually favorable eclipse of August 30, 1905, offered a hope that large-scale photographs of the corona secured in Labrador, Spain, and Egypt, or in two of these countries, would enable us to detect changes in the coronal structure occurring between the instants of totality in those countries. Dr. PERRINE and I have made careful comparisons of the coronal images recorded by the Crocker Eclipse Expeditions in Spain and Egypt. A number of fairly well-defined nuclei of the corona existed both east and west of the Sun. As a result of these comparisons we are able to say that there is no certain evidence of motion having occurred in the interval of 70 minutes which elapsed between the instants of totality in Spain and Egypt. Details of structure within the nuclei have suffered change, but the mass as a whole cannot have moved so much as one mile per second during the interval. Greater speeds might well have occurred in the principal coronal streamers without our having detected them; for their structure is uniform and regular, and well-defined nuclei are absent. Thus, in the cases where high speeds should perhaps be most naturally expected, photographic plates have little power to record them.

Measures of motions of approach and recession within the corona by means of the spectrograph are unpromising, for several reasons. The coronal light is intrinsically weak, and exposures are from necessity short. The brighter parts of the corona radiate light forming a continuous spectrum, neglecting the almost insignificant component which gives rise to bright lines. Even if spectrograms of the middle and outer coronal regions could be secured with the Fraunhofer lines recorded in good strength, their interpretation would be difficult and somewhat unpromising. The slit of the spectrograph would receive light from streamers which radiate in a variety of directions from the Sun. There would be streamers pointing both toward and away from the observer and streamers occupying positions of all values intermediate between these limits. If the coronal particles were moving outward exclusively, the general effect would be to cause a shift corresponding to recession, but the lines would be broadened. Particles moving *toward the Sun would in* effect displace in the direction

of approach, at the same time broadening the lines. It will be easy for the reader to determine the effect of a motion of either kind in a streamer making a given angle with the observer's line of sight, and space will not be taken here to summarize further the general effect. It is evident that a dark-line spectrum, if one of sufficient density and dispersion could be obtained, would be of great complexity. However, a knowledge of the motions within the corona would doubtless be our most effective power in determining the origin of the corona, and the subject should not be abandoned as hopeless.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	May 4,	$1^h 53^m$ P.M.	Last Quarter..	June 2,	$9^h 20^m$ P.M.
New Moon....	" 12,	12 59 A.M.	New Moon....	" 10,	3 50 P.M.
First Quarter..	" 20,	5 27 A.M.	First Quarter..	" 18,	6 55 P.M.
Full Moon....	" 27,	6 18 A.M.	Full Moon....	" 25,	1 27 P.M.

The summer solstice, the time when the Sun stops moving north and begins to move south, occurs June 22d, 6 A.M., Pacific time.

Mercury is a morning star on May 1st, rising less than an hour before sunrise, and is therefore too near the Sun for naked-eye observation. It moves rapidly toward the Sun, and passes superior conjunction, becoming an evening star, on the night of May 23d-24th. It then moves rapidly away from the Sun and a little northward. Shortly after June 1st it remains above the horizon an hour after sunset, and this period increases to about an hour and three quarters soon after the middle of the month. It then begins to shorten, but does not go below an hour and one half until after the close of the month. Greatest east elongation ($25° 29'$) is reached on June 27th. This is not quite the maximum possible, but is not much below it. The month of June this year therefore

gives about the best opportunity for naked-eye views of *Mercury*.

Venus remains a morning star, rising $1^h\ 20^m$ before sunrise on May 1st, and this interval remains about the same throughout the two-month period, even increasing a little toward the end of the period, although the apparent distance between planet and Sun is diminishing, the distance apart of the two bodies being 8° less at the end of the period than it was at the beginning. Although the planet is very low down until nearly the time of sunrise, its brightness is so great that there will be no difficulty in seeing it during the early twilight.

Mars rises shortly before midnight on May 1st, before $10^h\ 30^m$ on June 1st, and before $8^h\ 30^m$ on June 30th. It moves eastward about 7° until June 5th, and from that time until the end of the month it moves westward about 4°. It remains in *Sagittarius*, north of the "milk-dipper" group. Its distance diminishes from sixty-nine millions of miles on May 1st, to fifty millions on June 1st, and thirty-nine millions on June 30th. At the last date its distance is only about one million miles greater than the minimum, which will be reached early in July. The planet will still gain materially in brightness all through the period, and will practically have attained its maximum at the end of June. It will then be about as bright as Jupiter. *Mars* will come to opposition on July 6th, and its nearest approach to the Earth will occur a few days later, the least distance being a little less than thirty-eight millions of miles. This is the most favorable opposition since that of 1892, which came on August 3d. The planet was then two and one-half millions of miles nearer the Earth than it will be during the present opposition,—not a great difference, but noticeable. The next opposition will come toward the end of September, 1909. This will be rather more favorable than the present one. The most favorable time is when opposition and perihelion come at about the same time. This happens when opposition occurs near the end of August. The present opposition occurs eighty-two days before time of perihelion; that of 1909 will occur about half of that time after perihelion. The sidereal period of *Mars* remains practically constant (687 days), somewhat less than two years. This is the time from one perihelion to the next. The synodic period, or time *from opposition* to opposition, averages 780

days, somewhat over two years, but is subject to considerable variation, about fifty days, the longest period coming when opposition occurs near time of perihelion. From the last opposition to the present one the interval is 788 days, and the next period will be considerably longer. The cause is the eccentricity of *Mars's* orbit, and the consequent variability in the velocity of the planet.

Jupiter sets shortly before $11^h\ 30^m$ P.M. on May 1st, and shortly after 8^h P.M. on June 30th. It moves eastward about 13° in the constellation *Gemini* and at the close of the period is nearly due south of *Castor* and *Pollux*, the principal stars of the constellation. It is in conjunction with *Mercury* on June 15th, the latter passing 1° 41′ to the north.

Saturn is a morning object, rising somewhat less than two hours before sunrise on May 1st, at $1^h\ 26^m$ A.M. on June 1st, and at $11^h\ 35^m$ P.M. on June 30th. It moves about 3° eastward and 2° northward in the constellation *Pisces*, and at the end of June is only about 2° distant from the point marking the vernal equinox. The rings are practically out of sight during May and June, as the Earth and Sun are on opposite sides of the plane. Large telescopes may show the edge illuminated, and possibly light may pass through small gaps in the rings. A better opportunity for seeing the same phenomenon will come during the autumn, when Earth and Sun will have changed places relative to the rings.

Uranus rises shortly before midnight on May 1st, and shortly before 8^h P.M. on June 30th. It is still in the constellation *Sagittarius* and moves westward about 2° during the two months. It is in conjunction with *Mars* on May 1st, which passes between it and the "milk-dipper" group at a distance of 0° 46′ from *Uranus*.

Neptune is in *Gemini* not far from *Jupiter*. The time of nearest approach is May 21st. *Jupiter* then passes 1° north of *Neptune*.

(FIFTY-SIXTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Dr. A. KOPFF, astronomer, Heidelberg.

Germany, for his discovery of an unexpected comet on August 22, 1906.

Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, March 20, 1907.

(FIFTY-SEVENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor H. THIELE, astronomer, Copenhagen, Denmark, for his discovery of an unexpected comet on November 20, 1906.

Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, March 20, 1907.

(FIFTY-EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to J. H. METCALF, astronomer, Taunton, Massachusetts, for his discovery of an unexpected comet on November 14, 1906.

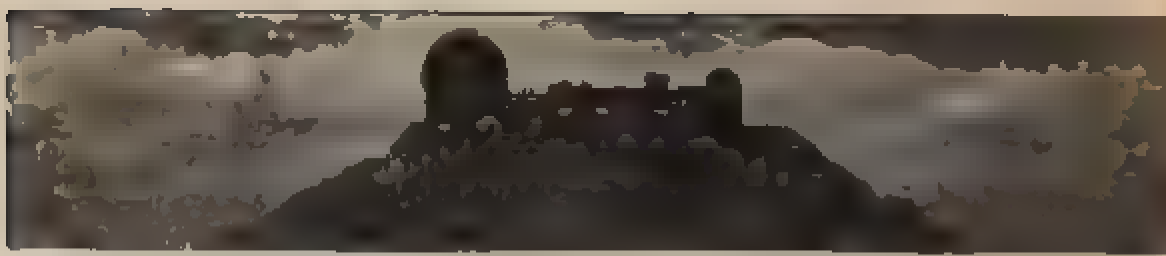
Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, March 20, 1907.

LIBRARY NOTICE.

Members who had in their possession at the time of the San Francisco fire any books or pamphlets belonging to the Library of the Astronomical Society of the Pacific are requested to send them to the Librarian of the Society, R. T. CRAWFORD, Students' Observatory, Berkeley, Cal.



NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on Comet Holmes.

Search was made for Comet Holmes with the 36-inch telescope on several nights before its rediscovery by photography by Professor Wolf, on August 28, 1906, and also on several nights in September. The conditions were fairly good, and an object as bright as 15th magnitude ought to have been detected, but the comet was not seen.

According to the corrections to Zwiers's ephemeris given by the photographic observations, the comet's place was certainly examined, and it is therefore safe to conclude that its visual magnitude was below 15.

Poor seeing on moonless nights in late October, when the comet reached its maximum theoretical brightness, and in the following months, prevented further search.

March, 1907 R. G. Aitken.

A Simple Method of Computing the Lengths of Slender Uneclipsed Solar Crescents.

In a note on the contact times of the total solar eclipse of 1898 Professor Campbell called attention to the fact that the times as computed from the data of the different ephemerides were not as consistent as might be wished, but in the case of that eclipse, as well as with earlier ones, there seems to be no evidence of a systematic variation of the observed from the computed times. For the eclipse of May 28, 1900, the preliminary report of the Lick Observatory–Crocker Eclipse Expedition to Georgia shows a difference of some seven or eight seconds between the computed and observed times of second contact. At the eclipse of August 30, 1905, the discrepancy was found to be greater. The Lick Observatory party reported a difference of seventeen seconds for second contact and twenty-three for third, while other observers also found that totality occurred about twenty seconds earlier

than predicted. The difference is understood to be due to the increasing error of the Moon tables at present in use.

To obtain a very approximate time for the beginning of totality which shall be practically independent of the error of the lunar tables, the interval before the beginning of totality that the uneclipsed crescent of the Sun subtends a definite angle at the Sun's center may be computed. A number of observers have used this method, and Dr. DOWNING has computed these data for the eclipse of January 3, 1908. In addition to the times of contact computed in the ordinary way, he gives the times before the commencement of totality corresponding to cusp angles 90°, 60°, 45°, 30°, and 15°. A note on the method used here in recomputing these values might not be without interest to eclipse observers.

The ordinary eclipse formulæ give us the following:—

d = Duration of totality.

P_2 and P_3 = Points of contact II and III, with their position-angles from the E-W line.

Let a = semi-diameter of Sun in seconds of arc, and b = semi-diameter of Moon in seconds of arc, corrected for augmentation. Draw the E W and N S lines through O, the center of the Sun.

Then, if C_2 and C_3 are the positions of the Moon's center at contacts II and III, they will lie on $P_2\,O$ produced and $P_3\,O$ produced, respectively, each at a distance $b - a$ seconds from O. A line drawn through C_2 and C_3 will be the path of the Moon's center relative to O, and the distance $C_2\,C_3$ will be traversed in d seconds of time. The velocity of the Moon's motion in seconds of arc per second of time is therefore $\frac{C_2\,C_3}{d}$. This velocity is readily obtained, since in the triangle $O\,C_2\,C_3$, the sides $O\,C_2$ and $O\,C_3$ are known, and the angle at O is the supplement of the sum of the position-angles.

Suppose the Moon's center at L when the semi angle at the Sun's center subtending the arc joining the cusps of the uneclipsed crescent is α. Draw $L\,M$ and $O\,M$ to one of the cusps, and also $L\,O$, which bisects the angle subtending the cusps.

From the triangle $L\,O\,M$, $L\,O$ may now be computed, having which, the triangle $L\,C_2\,O$ is solved for $L\,C_2$. This is the

distance over which the Moon's center must move before beginning of totality, and the velocity being known, the time is also determined.

G. B. Blair.

March, 1907.

Increased Water Supply on Mt. Hamilton.

The following description of a new pumping plant at Mt. Hamilton is published for its possible interest to other mountain observatories.

Up to the present time the Lick Observatory has obtained its water supply from a small spring (Aquarius) in the north cañon, located about one mile northeast and 325 feet lower than the observatory buildings. The flow from this spring exceeded the consumption in the late winter and early spring months and fell far short of the consumption in the summer and fall months. The storage and distributing reservoirs on Kepler Peak, one half mile east and fifty feet higher than the buildings, supplied the deficiency during the dry season. The needs of the observatory for household and photographic purposes were met by this system, provided the rainfall for the year had been normal and constant care was taken to guard against leaks in the system. In seasons when the rainfall fell below the normal, it was necessary to use the water under short-allowance rules. This has occurred four or five times during the history of the observatory and has been a serious matter, especially as the system of fire protection was impaired just at the time of the year when it was most needed.

Plans were formed two years ago to increase the water supply, based upon the use of a spring in the south cañon, which is 300 feet lower than Aquarius, but whose flow is at least fifteenfold greater than that of Aquarius.

The system of pumping is a somewhat novel one, and I am under great obligations to Mr. J. A. Lighthipe, head of the Engineering Department of the General Electric Company in this district, for calling my attention to it.

The spring is 680 feet lower than the Kepler reservoirs, and the distance between the two, measured on the thirty-degree slope, is 1,400 feet. Catchment reservoirs, capacity 12,000 gallons, have been established at the spring. A two-inch power and supply pipe leads from these reservoirs farther down the steep cañon, a distance of 700 feet on the slope, and

215 feet in altitude. At this lower level an hydraulic motor pump is installed. This is constructed very much like an ordinary steam pump, except that the steam cylinders are replaced by water cylinders, forming the motor. The pipe last described divides into two branches just above the pump. One of these connects with the motor end of the pump and the other with the pumping end. The piston areas for the two motor cylinders are sixfold greater than the areas of the pumping pistons. The large motor pistons, operated by six gallons of water with 215 feet head, enable the small pumping pistons to lift one gallon through the 2,100 feet of two-inch pipe to the Kepler reservoirs, 895 feet in altitude above the pump. In other words, the pump places one gallon in seven in the Kepler reservoirs, the other six gallons doing the work. The simple device of dividing the power pipe just above the pump so as to supply water to the pump-end under a pressure of 215 feet, increases the efficiency of the pumping system to this extent.

The only personal attention required by the pump consists in filling the oil cups once a week. The pump was constructed by the Dow Pumping Engine Works, San Francisco, under the guarantee that it would do the work described.

At the present time the pump is delivering 6,200 gallons per day to the Kepler reservoirs. Our average daily consumption throughout the year is about 1,700 gallons. It is expected that one gallon in seven during the late summer and fall months will deliver about 1,200 gallons per day. With the 200,000 gallons stored in the Kepler reservoirs, and with the Aquarius pumping system available in case of need, it is believed that our annual anxiety as to the water supply will be eliminated. During the dry season the available water supply will be three- or fourfold greater than it has been in the past.

An electric pumping plant is replacing the steam plant at Aquarius.

W. W. CAMPBELL.

MT. HAMILTON, March 25, 1907.

NOTE ON COMET *a* 1907 (GIACOBINI).

The first comet of this year was discovered close to opposition, March 9th, by GIACOBINI, at Nice. From the first three available observations (March 9th, by GIACOBINI, at Nice; March *11th, by RICE, at Washington*; March 12th, by FATH,

at Mt Hamilton) a preliminary orbit was computed. The elements and ephemeris are given in *Lick Observatory Bulletin*, No 111

Dr. AITKEN states that "the comet as seen here on the first date was very small, round, with well marked condensation, and almost equal to an eleventh-magnitude star in brightness" It is now receding from the Earth.

The observations are satisfied by a parabola. The comet has a retrograde motion, the plane of its orbit having an inclination of 142° to the ecliptic Its nearest approach to the Sun was on March 12th, at which time it was 190,000,000 miles, or 2 05 astronomical units from it. The longitude of perihelion is 50°; the longitude of the ascending node is 96°.

Having no later observations from the East, and not having one from Mt. Hamilton because of the position of the Moon and the continual rain in California, it has been so far impossible to obtain a second orbit.

STURLA EINARSON
ESTELLE GLANCY.

BERKELEY ASTRONOMICAL DEPARTMENT, March 27, 1907

NOTE ON COMET *b* 1906 (KOPFF)

This comet was discovered in March, 1906, by KOPFF, at Heidelberg. Its geocentric motion was very small From a twenty-two day arc a set of parabolic elements was computed by Mr CHAMBERLIN and myself and published with an ephemeris in *Lick Observatory Bulletin*, No 97. The remarkable feature of the orbit is the great perihelion distance, 3 3 astronomical units. Because of its great distance from the Sun its heliocentric motion in the last year has been but 50°. The Earth has therefore overtaken the comet, and it was picked up again March 21st of this year by KOPFF. The residuals for this place from our orbit are (O–C) $\Delta\alpha = -0°.6$; $\Delta\delta = +0°.1$. A change of about eight days in the time of perihelion passage will remove the greatest part of these No attempt will be made to improve these elements on the basis of this year's observation since Professor WEISS has found and published in *A. N.* 4154 a set of elements and ephemeris which represent this place almost exactly. WEISS's elements have been deduced from observations extending from January, *1905, to May, 1906* The position of January, 1905, is from a

photographic plate by Professor WOLF, found after the comet had been discovered by KOPFF. More than 800 days have elapsed since this observation of January, 1905, so that, excepting the periodic comets, this comet holds the record for length of time during which it has been under observation. It is further highly probable that it will be picked up when the Earth overtakes it again next year.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, March 30, 1907.

THE PROMOTION OF DR. AITKEN.

It gives me great pleasure to announce that Dr. R. G. AITKEN has been promoted to the position of Astronomer in the Lick Observatory. It is unnecessary to say that this action on the part of the President and Regents of the University is thoroughly deserved. It would be difficult to speak too highly of Dr. AITKEN'S scientific researches. His work on double stars is certainly unsurpassed in quantity, quality, system, and breadth of view.

W. W. CAMPBELL.

PROMOTION OF PROFESSOR LEUSCHNER.

The promotion of Dr. A. O. LEUSCHNER, Director of the Students' Observatory, from Associate Professor to Professor of Astronomy is another well-earned event which it gives us pleasure to record. Professor LEUSCHNER has built up one of the strongest and best of astronomical schools; and although his teaching, and administrative duties both inside and outside of his department, have been heavy, he has found time to make valuable investigations and to encourage and direct similar investigations by the assistants in his department. The publication of Professor LEUSCHNER'S work on the Watson asteroids is awaited with interest.

W. W. CAMPBELL.

REPORTS OF OBSERVATORIES.[1]

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

The work of the Chamberlin Observatory during 1906 was confined to observations of comets, the installation of some new apparatus, and some special studies in personal equation.

H. A. HOWE, *Director*.

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

The programme of the International Geodetic Association for observing variations of latitude was changed at the beginning of 1906 by dropping the twenty-four refraction pairs (pairs which culminate at large zenith-distances, about 60°), and also six of the latitude pairs, and substituting for these new latitude pairs. The observing-list now consists of ninety six pairs, distributed throughout the twenty-four hours of right ascension, sixty-six of which belong to the old list and thirty of which are new. All of the stars culminate at zenith-distances of less than 26°.

Observations continued throughout 1906 without serious interruption from any cause. The weather was favorable during all months except February, March, and December, a monthly total of less than 150 pairs being considered unfavorable. The three longest intervals without observations were fourteen nights in August, eight nights in January, and six nights in each of February, November, and December. The first of these was caused by the absence of the observer and the others by unfavorable weather. The rainfall for the year was 51.8 inches. The maximum temperature was 108° F., on July 24th; the minimum temperature 22°, on November 24th, 28th, 29th.

The following table gives a summary of the observations made for the variation of latitude. The first column contains the number of determinations made each month, the second column the number of nights upon which observations were made, the third column the number of complete nights (sixteen determinations), the fourth column the greatest interval in each month during which no observations were obtained.

[1] Arranged alphabetically according to name.

1906.	Pairs.	Nights.	Nights.	Nights.
January	175	13	8	8
February	114	10	5	6
March	138	11	7	5
April	203	14	11	5
May	180	13	9	5
June	220	18	12	3
July	247	16	15	5
August	224	14	14	14
September	263	17	16	3
October	238	17	14	4
November	212	15	11	6
December	144	12	7	6
Totals	2,358	170	129	
Means	196.5	14	11	6

Definitive reductions of all the observations for the variation of latitude (233) obtained between April 4th and May 4th, both inclusive, were made in order to determine if possible whether or not there was an appreciable shift in the Earth's crust at Ukiah at the time of the earthquake of April 18th. No sudden change in the latitude was found. The results of the computations were printed in these *Publications* (vol. XVIII, p. 241).

SIDNEY D. TOWNLEY, *Astronomer-in-Charge.*

LICK OBSERVATORY, MT. HAMILTON, CALIFORNIA.

The scientific work of the Lick Observatory during the calendar year 1906 was pursued by each member of the staff with his accustomed industry and enthusiasm. It related for the most part to advancing the solution of the greater problems upon which we have been engaged in past years, and only here and there were minor or new problems taken up.

Professor TUCKER, with the aid of Mr. R. F. SANFORD, Carnegie Assistant, has completed the extensive reductions of his meridian-circle observations of 2,800 zodiacal stars, and the manuscript results are nearly ready for publication. The purpose of these observations is to provide more accurate reference-points in the zodiac as a basis for securing improved orbits of the planets.

Mr. TUCKER continued throughout the year the observation of a carefully constructed programme of stars, for the purpose

of securing a system of star places of the highest accuracy, which shall be strictly *fundamental*, as opposed to basing observations upon a system established with other instruments. There is need in these observations for the most accurate clock that can be secured, and a Riefler constant-pressure clock, with nickel-steel pendulum, was installed late in 1906.

A special list of stars, used by Professor DOOLITTLE, of the University of Pennsylvania, in a study of terrestrial latitude variations, has also been observed by Mr. TUCKER.

Out of 965 photographs of the minor planet *Eros*, made at the favorable opposition of 1900, 525 have been selected as a basis for improving our knowledge of the Sun's distance from the Earth. Excellent progress in the measurement and reduction of these photographs has been made by Miss CHASE and Miss HOBE, Carnegie Assistants, under the supervision of Dr. PERRINE. Another year should see the work well along toward completion. There will be nothing of special interest to communicate to general readers until all the measures are combined in a final solution for the most probable value of the Sun's distance.

Good progress has been made in the study of the eclipse photographs of 1905, obtained by the Crocker Expeditions to Spain and Egypt.

Mr. PERRINE has made a careful examination of the photographs secured in Spain and Egypt for the intramercurial-planet search. The Spanish plates record stars in the region examined down to about the eighth photographic magnitude, but all of the images observed on the plates have been identified as those of well known stars. Assuming that the planet would be one magnitude fainter photographically than visually, the search may be said to prove that no planet as bright as the seventh magnitude exists within the region searched. This includes an area about 9° by 29° lying along the direction of the Sun's equator.

It will be remembered that similar search made at the Sumatra eclipse of 1901 by Mr. PERRINE was limited in one third of the area to stars brighter than the sixth photographic magnitude. The Spanish results are thus an extension and advance of those secured in Sumatra. It is becoming more apparent that the anomalous motion of *Mercury's* perihelion must seek an explanation elsewhere than in the attractions of

intramercurial planets. A paper published very recently by Professor SEELIGER makes it extremely probable that the hitherto unexplained anomalies in the motions of the four inner planets are due to the attractions of the widely distributed materials responsible for the zodiacal light. It is unfortunate that clouds limited the observations in Sumatra and Spain. The cameras employed are capable of recording tenth-magnitude stars with clear skies and exposures of three minutes or less. It is hoped that an eclipse of the near future will enable this limit to be reached and thus give completeness to the observational programme.

The unusually favorable eclipse of 1905 afforded a hope that large-scale photographs of the corona secured in Labrador, Spain, and Egypt, or in two of these countries, would enable us to detect changes in the coronal structure occurring between the instants of totality in those countries. Dr. PERRINE and I have made careful comparisons of the photographs secured in Spain and Egypt. A number of well-defined nuclei existed both east and west of the Sun. Details of structure within the nuclei suffered change, but the masses as a whole appeared to remain in fixed positions. We are able to say that those masses could not have moved so much as one mile per second during the interval of seventy minutes which elapsed between the totalities in Spain and Egypt. Greater speeds might well have occurred in the principal coronal streamers without our having detected them; for their structure is uniform and regular, and well-defined nuclei are absent. Thus, in the cases where high speeds should perhaps be most expected, the photographic method has little power to detect them.

In connection with the Sumatra eclipse, Mr. PERRINE was able to reach the interesting conclusion that a large disturbed volume of the corona, conical in form, appeared to be situated exactly over the large and only sun-spot visible during several days preceding and following the eclipse. A very similar disturbed volume is shown on the coronal photographs of 1905. The vertex of the cone does not appear to be over one of the large spots then existing on the Sun, but it is above a large region of the photosphere which shows many signs of disturbance.

The complete reduction of the time and longitude observations in Spain confirms definitely the conclusion reached on

eclipse day,—that mid-totality occurred twenty seconds earlier than the time predicted by the nautical almanacs

It is hoped that the spectrographic and polarigraphic results will be ready for publication within the coming year.

The D. O. Mills Expedition to Chile terminated its first period of activity on March 1, 1906. At that time Dr. CURTIS assumed charge for the second period of five years, in succession to Professor WRIGHT, who returned to California shortly thereafter. The working programme of the original expedition called for spectrograms of all the brighter stars south of declination −25° which should contain lines capable of accurate measurement, down to photographic magnitude 5.5. The stars so selected formed a list of 143. Four spectrograms were obtained of practically every star on the list, and additional ones of many others were taken for special purposes. Eight hundred spectrograms in all were obtained. The half of these were definitively measured and reduced by January, 1907, and it is expected that the results from the other plates will be ready by the middle of the present calendar year.

I am inclined to ascribe great importance to this programme of work, now nearing completion in accordance with plans which have been definitely held in mind since 1894. There is a tremendous demand for the knowledge of the velocities of the stars determined spectrographically, for use (*a*) in determining the motion of the solar system as a whole, and (*b*) in determining the structure of the sidereal universe. Observations of this kind either have been made or are under way at ten northern-hemisphere observatories. The southern two sevenths of the sky, out of reach of northern instruments, must be observed in the same manner before a satisfactory solution of these problems can be hoped for, and before the observations of the northern stars can assume their full value. Up to 1906 existing southern-hemisphere observatories have published spectrographic velocities of but two or three stars. The Mills Expedition was organized to secure observations of the brighter stars with special reference to their use in problem *a*.

In the erection of the observatory on Cerro San Cristobal, Santiago, during the rainy season, in meeting and overcoming difficulties as they arose, and in carrying out the programme of observation as planned within the estimated time, Acting-

Astronomer WILLIAM H. WRIGHT, in charge of the expedition, is entitled to great credit.

The dearth of southern hemisphere observations of the exact kinds that the Mills Observatory is fitted to supply made it extremely desirable that our station should continue in active existence. When the subject was presented to Mr. MILLS, he was pleased to provide for its liberal support through a further period of five years, and for many improvements and additions to the instrumental equipment. Dr. CURTIS, in charge of the expedition during its second term, is assisted by Mr. GEORGE PADDOCK, formerly of the University of Virginia.

The determinations of the radial velocities of the stars on Mt. Hamilton by means of the Mills spectrograph attached to the 36-inch equatorial made good progress during the year 1906. About 400 spectrograms were secured, principally by Messrs. CAMPBELL, MOORE, and WRIGHT. The stars observed were, on the average, fainter than in former years. This involved longer exposures, and resulted in a slightly reduced number. A considerably larger number of spectrograms taken in 1906 and former years were measured and reduced definitively, principally by Messrs. MOORE, BURNS, and NEWKIRK.

Professor AITKEN's programme of double-star observations with the 12-inch and 36-inch refractors has two main purposes: (*a*) to examine systematically all the stars to the ninth magnitude inclusive between the North Pole and $-22°$ of declination, checking the positions of all previously known double stars and noting all additional pairs that are under five seconds in distance, as the basis for a thorough statistical study of double stars; and (*b*) to measure regularly all known double stars showing motions of revolution, especially the more rapid and difficult pairs, to provide data for improving our knowledge of their orbits.

Approximately, 300 new pairs were discovered in the year. Seventy five per cent of them are under two seconds of arc. This work involved careful examination of 10,000 stars, in round numbers. The total number of new stars discovered by Messrs. AITKEN and HUSSEY, who co-operated in organizing and prosecuting this double-star survey, is about 2,900. Given reasonably good winter skies, the programme for the northern hemisphere should be completed by Dr. AITKEN within three years.

The second part of Dr. AITKEN's programme is thoroughly systematized, so that observations of the more rapid and difficult pairs are obtained at the times most advantageous for determining their orbits.

A considerable number of micrometer observations of the comets of 1906 have been made by Messrs. AITKEN, MADDRILL, SMITH, and FATH.

A large number of photographs of *Jupiter's* sixth and seventh satellites have been obtained by Dr PERRINE with the Crossley reflector for the purpose of improving our knowledge of their orbits Photographs of *Saturn's* ninth satellite and *Neptune's* satellite have also been secured. Extensive experimental work with reference to future investigations with this instrument have also been conducted by Dr. PERRINE

Very extensive observations of several well-known variable stars have been made with the one-prism spectrograph by Messrs. ALBRECHT and MADDRILL, as a basis for theses, in partial fulfillment of requirements for the degree of Doctor of Philosophy. In all cases these variables have been shown to be spectroscopic binaries, and their accurate observations will be of great value in the efforts that are constantly being made to determine why these and other stars of their class vary in brightness.

Mr. MADDRILL has given special attention also to the photometry of several variable stars with a view to determining possible relationships between peculiarities in their brightness- and velocity-curves. His photometric results are of very satisfactory accuracy.

A fruitful investigation has been made by Dr. ALBRECHT on the relation of the effective wave-lengths of blended spectral lines and stellar spectra of different types He has shown that the effective wave-lengths of many blends change progressively with the spectral type.

A long list of minor investigations and results should for completeness be mentioned, but space is lacking.

The observatory has abundant cause for thanksgiving in that the great earthquake of April 18th did very little damage. Reference may be made to an article on this subject in an earlier number of these *Publications.* The D O Mills Observatory, Chile, had its corresponding experience only four months later, and was equally fortunate. Let us hope that

these trials, so closely connected in time and giving rise to so much anxiety, were but a horrible coincidence, and that they may not recur for many generations

The installation of an important electric plant for lighting and power purposes began in May, under the difficult conditions of supply, labor, and finance induced by the earthquake and fire It should be completed early in the year 1907 An automatic pumping plant, installed at the same time, is in operation, and promises to increase the water supply three- or fourfold, with little expense.

Acknowledgments are due to the Regents of the University of California, to Mr D O. Mills, to Mr. W. H. Crocker, and to the Carnegie Institution for generous financial support, and to all the members of the Observatory Staff for their enthusiastic and efficient aid in carrying out the scientific plans

W. W Campbell, *Director.*

LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA.

During the first part of the year the large telescope was employed in spectrographic work, the charting of star-fields with the Brashear photographic doublet and micrometric observations Since July the doublet has been mounted on the 6 inch Clark refractor, and the time of the large telescope has been devoted, for the greater part, to spectrographic observations During the summer and autumn further experiments in planetary photography were carried on.

Mr Slipher's programme of spectrographic work has consisted principally of line-of sight observations of stars Modification of parts of the large three prism spectrograph were made by Brashear in January, February, and March The changes made, remounting of the prisms and providing the collimator with a curved slit, have proved very satisfactory, and have added much to the efficiency of the instrument. Observations were made with the three-prism spectrograph until the middle of August. During the autumn months spectrographic observations of the fainter stars were made with the single prism spectrograph. The original mounting for the simple prism which made use of the spectrometer section of the large spectrograph, lacked stability for long exposures. But after modification of this part, from designs by Mr.

SLIPHER, no trace of flexure has been found for exposure of as much as four hours' duration on the one side of the meridian. In the single prism instrument one of the dense flint prisms of the prism-train of the large spectrograph has been used. This prism gives a dispersion of 35 tenth-meters per millimeter at $H\gamma$. By tipping the plate the camera is made to give a sharp focus over the range of spectrum comprised between K and λ 4600, over which region the measures are commonly extended. In the course of this work several stars have been found to have variable radial velocity, and the spectrum of ϵ *Capricorni* has been found to contain bright lines. Though the measurement of the plates is much in arrears, the results thus far obtained indicate a large field of work for this form of instrument. Of the spectra of variable stars photographed with the single-prism instrument the most interesting is perhaps that of *Mira Ceti*, secured at the recent unusually bright maximum of this star during December and January. One spectrogram was made with the three-prism instrument. With the improved sensitizing dyes now available, giving a fairly even deposit over the entire range of sensitiveness of the plate, it was possible to photograph the spectrum with the single-prism instrument from below B to $H\delta$. All the hydrogen lines covered by the plate are bright. (See note in the *Astrophysical Journal* for January, 1907, and the reproduction of one of the plates of the spectrum in the March number of that publication.) In connection with the spectrographic work, Mr. SLIPHER has experimented further with sensitizing dyes, particularly those active for the less refrangible end of the spectrum, for the application of such to photographic investigation of absorption bands in planetary spectra and also for work on the lower end of stellar spectra, with the result that plates more sensitive to the red can now be prepared. The greater rapidity and more perfect gradation of these plates than of those formerly available makes it possible to extend the study of the spectra of planets and stars considerably farther into the red.

A great many star fields have been photographed with the Brashear doublet during the year. This lens was at first carried on the 24-inch refractor. When the mounting of the 6 inch Clark refractor was completed, in July, the doublet was mounted on it, and since then the time of this instrument has been devoted wholly to photography. This work was done

until June by Mr. J. C. DUNCAN, Lawrence Fellow at this observatory for 1905-1906. Since July the work has been continued by Mr. E. C. SLIPHER, fellow for the present year.

In addition to making photographs of star-fields and the series of photographs of Comet *c* 1905, Mr. DUNCAN made micrometric measures for position of Comets *c* 1905, *a* and *b* 1906.

In view of the approaching favorable opposition of *Mars*, further experiments in planetary photography have been carried on by Mr. LAMPLAND. It is hoped that the greater brightness and larger disk of the planet, together with such improvement as may be expected from past experience and more suitable and efficient apparatus, will bring still better results than were obtained in 1905. For the present, at least, the greatest value of the results obtained by photography is the evidence the negative brings to corroborate data obtained visually. The great mass of observational data and the results deduced therefrom, accumulated since SCHIAPARELLI'S epoch-making observations were begun, have been obscured and distorted more or less by unfounded skepticism, based on the idea that many of the observed phenomena are subjective effects or spurious products of observation. The questions raised have been thoroughly investigated from the standpoint of theory and experiment and found untenable. With the further confirmation of the visual results by photography, it seems that there should be no room for doubt in the matter.

PERCIVAL LOWELL.

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

As indicated in the last annual report, this observatory was established mainly for keeping up the public time service for the Pacific Coast, and for the rating of chronometers used in the naval service. During the past year the work has been maintained as usual.

At the time of the great earthquake the time-signals were sent out the following day, but the Western Union Telegraph Company's lines were so deranged and congested with business that the signals could not always be delivered. Yet even during this trying period they managed to deliver the signals about every second day, which was sufficient for commercial purposes. The earthquake stopped two of the four clocks of

the observatory, and deranged the time of the other two by more than twenty seconds. The pendulums rubbed against the index ledges, and this with the shocks affected the rates of motion.

The earthquake was carefully observed here, and a full report has been submitted to the State Earthquake Commission. After this terrible disaster to the State, the theory of earthquakes ordinarily adopted seemed so improbable and so incapable of explaining the observed phenomena that a general survey of the subject was attempted, in the hope of gaining a better understanding of the cause of such disturbances. The results of this investigation have just been published in the *Proceedings* of the American Philosophical Society at Philadelphia. It is shown that the main cause of great earthquakes is the expulsion of lava from under the bed of the sea, by the explosive power of steam, which forms beneath the Earth's crust, owing to the secular leakage of the ocean bottoms. Another investigation is about finished which deals with the problem of the secular cooling of the Earth and the theory of contraction, so generally adopted in the physical sciences. The results obtained are not without interest to investigators.

A new Riefler clock, moving in an air-tight case, has just been installed in the observatory, and it promises to perform with great perfection, and will thus afford additional accuracy to the time service in the winter season, when long spells of cloudy weather are common.

T. J. J. SEE,
Professor of Mathematics, U. S. N.,
in charge of the Observatory.

SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, MT. WILSON, CALIFORNIA.

The most important event of the year, so far as its bearing on the future of the observatory is concerned, was the gift of $45,000 by Mr. JOHN D. HOOKER, to meet the cost of a mirror of one hundred inches aperture for a great reflecting telescope. The difficulties in the way of constructing and using successfully a mirror of this size have been outlined elsewhere. It is sufficient to say here that the mirror is certain to give results of great importance in those classes of work where the finest definition is not essential, while there is good reason to hope

that for the direct photography of nebulæ, and for other investigations requiring even more perfect definition, there will be some nights in the year in which the full advantages of the large aperture will be realized. The glass disk has been ordered from the plate-glass works at St. Gobain, France, and work has been undertaken on the fireproof structure in which the grinding and polishing of the mirror will be done by Professor RITCHEY.

The work of research has included:

1. Daily photography of the Sun with the photoheliograph;
2. Daily photography of the Sun with the spectroheliograph;
3. Photography of the spectra of sun-spots;
4. Photography of the flocculi, for the determination of the radial velocity of the calcium vapor;
5. Spectrographic investigations of the solar rotation;
6. Bolographic investigations of the solar absorption;
7. Special studies of stellar spectra with a spectrograph of high dispersion;
8. Laboratory investigations;
9. Preliminary studies of the correlation of solar and magnetic phenomena.

The 5-foot spectroheliograph was erected in the Snow telescope-house in October, 1905. It has given admirable results from the outset, the daily records including photographs of the Sun with the calcium, hydrogen, and iron lines. These photographs have been studied in various ways, the principal routine investigation in which they are employed being a determination of the solar rotation. The daily motions of the calcium flocculi required for this purpose are measured by Miss WARE, with the "heliomicrometer," an instrument which permits the latitude and longitude of points on a photograph of the Sun to be measured directly, without computation. This instrument was constructed in the observatory shop and has been thoroughly tested during the year. Measures can be made with it as rapidly as with ordinary measuring-machines, and apparently with no less precision.

A comparative study of the hydrogen and calcium flocculi indicates that the former lie at a somewhat higher level in the solar atmosphere. Stereoscopic comparisons of calcium photo-

graphs taken at intervals ranging from one to ten hours have also proved very instructive.

Much time has been devoted to the study of the spectra of sun-spots, for the purpose of interpreting the cause of the strengthening and weakening of solar lines. The photographs of spot spectra used for this work were taken by Mr. ADAMS and Mr. ELLERMAN with the 18-foot Littrow spectrograph, used in conjunction with the Snow telescope. These photographs show thousands of lines not previously recorded, and have served admirably for present investigations. For the interpretation of the changes in the relative intensities of the lines, many laboratory experiments were made by Dr. GALE. It was soon found that by varying the temperature of a metallic vapor, such as iron or titanium, the changes in the relative intensities of the lines observed in sun-spots could be closely imitated. This work, carried out systematically, led to the conclusion that the characteristic line intensities of spot spectra are probably the result of the reduced temperature of the spot vapors, as compared with those of the ordinary reversing layer. This conclusion was confirmed by the discovery in spot spectra of the flutings of titanium, which do not appear to be present at the higher temperature of regions outside of spots.

A study of the spectrum of *Arcturus*, photographed with a spectrograph of very high dispersion, showed that the lines that are strengthened in sun-spots are in general strengthened in this star, at least in the region investigated. Lines that are weakened in sun-spots also appear to be weakened in *Arcturus*. This is a natural result if we assume a spot to be a comparatively cool region on the Sun, and if we suppose *Arcturus* to be a star like the Sun, cooled to a temperature of the same order as that of sun-spots. The presence of titanium flutings in third-type stars affords another close bond of connection between these stars and sun-spots. Results of this character, when followed up with the aid of the 60-inch reflector, should throw much light on the temperature classification of stars.

The radial motion of the calcium vapor in the flocculi has been studied spectrographically by Mr. ADAMS. The average displacement of the H_3 and K_3 lines corresponds to a velocity of approach of the calcium vapor amounting to about 0.41^{km} per second. The varying displacements obtained at different times, however, indicate that general conclusions should be

based only on very extensive investigations. The results given by the bright lines H_2 and K_2 also show a displacement toward the violet, so that the calcium vapor in the flocculi may be regarded as moving upward.

Mr. ADAMS is engaged on an extensive study of the solar rotation, based upon comparative photographs of the spectra of opposite limbs, made with the 18-foot spectrograph of the Snow telescope. The results, so far as reduced, are very consistent, and should prove to be an important contribution to this subject.

Bolographic studies of the absorption of the solar atmosphere, made by Dr. PALMER, with the advice and co-operation of Mr. ABBOT, seem to indicate that the absorption may fluctuate in an irregular manner within short periods. No satisfactory conclusions can be drawn, however, until the investigation has been carried farther and correlated with simultaneous studies of the solar constant.

Professor E. F. NICHOLS, of Columbia University, carried on two special investigations during the summer. One of these was the study of the effect of the ionization produced by X-rays upon the absorption or radiation of a gas or vapor. The second investigation dealt with the question whether the "Reststrahlen" obtained after repeated reflections from rock-salt surfaces reach us in any appreciable amount from the Sun.

The latitude and longitude of the Solar Observatory were determined by Messrs. SMITH and MCGRATH, of the U. S. Coast Survey. The results obtained are as follows:—

	Mt. Wilson Triangulation Station.	Snow Telescope Pier.
Latitude	34° 12′ 59″.72	34° 12′ 59″.53
Longitude	118 3 45 .54	118 3 34 .89

The Smithsonian Institution sent a second expedition to Mt. Wilson during the summer of 1906, for the purpose of continuing the work undertaken in 1905. Although the season was hardly as satisfactory as the previous one, a large number of determinations of the solar constant were obtained. These are of a high order of precision, and should leave no doubt, when reduced, of the character of the variations which the results of 1905 seemed to exhibit. The admirable methods developed by Mr. ABBOT, in conjunction with the late Secretary LANGLEY,

seem well calculated to clear up the long-standing question as to the variability of the solar radiation.

The work of the Computing Division has been organized and placed under the direction of Mr. ADAMS. A series of offices added to our building in Pasadena provide suitable quarters for this work. Three computers, Miss WARE, Miss LASBY, and Miss SMITH, are at present employed. Miss WARE, as already stated, is engaged in the measurement of solar photographs with the "heliomicrometer." Miss LASBY is measuring Mr. ADAMS's photographs of spectra taken for the determination of the solar rotation. Miss SMITH is measuring the area of the calcium flocculi, in regions ten degrees square on the solar surface, for the purpose of ascertaining the distribution and variation of the solar activity. Special apparatus, devised for this purpose, was constructed in the observatory instrument-shop.

The work of the Construction Division has made admirable progress under the direction of Professor RITCHEY. Work has advanced on the 60-inch mirror and its mounting, the heavy parts of which were received from the Union Iron Works in the autumn. In addition, many smaller instruments have been constructed. The five-ton automobile truck, to be used for transporting the mounting of the large reflector and the steel for the building and dome in which it is to stand to the summit of the mountain, has also arrived in Pasadena. The work of widening the "New Trail" into a road is well advanced and will be completed in the spring. This work has been carried out under the immediate superintendence of Mr. GODFREY SYKES, of the Desert Botanical Laboratory of the Carnegie Institution, acting under the general direction and with the active co-operation of Professor RITCHEY.

Further details of the work of the year may be found in the Annual Report of the Director, in Year Book No. 5 of the Carnegie Institution, and in *Contributions from the Solar Observatory*, Nos. 3 to 14.

GEORGE E. HALE, *Director.*

STUDENTS' OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

The year ending December last has been notable for a marked increase in enrollment in the courses offered by the Berkeley Astronomical Department. The number of students

during the fall term of the year 1906 was 216, the same as the combined enrollment for the two preceding terms. With the enrollment during the current term, the attendance for the academic year (1906-1907) has reached 378, as against 216 for the preceding year.

The staff of the department has devoted practically all of its time to instruction and has had to forego the much-desired completion of several astronomical investigations. The department was further seriously handicapped during the fall term by a prolonged illness of Mr. EINARSON, the assistant.

Nevertheless, the regular computation by the "Short Method" of one or more preliminary orbits of all newly discovered comets was continued during the year, with the exception of one case, by Dr. CRAWFORD, generally with the assistance of graduate students.

In his capacity as member and secretary of the State Earthquake Investigation Commission, the Director has devoted much time to the collection and systematizing of data on the California earthquake of April 18th.

On July 1, 1906, Dr. CRAWFORD was promoted to be Assistant Professor of Practical Astronomy.

Important additions to the instrumental equipment have not been made. The observatory has been fortunate, however, in having the use of an Omori tronometer belonging to the Imperial Earthquake Investigation Commission of Japan. With the aid of this instrument numerous good records of after-shocks have been secured, as well as records of three earthquakes at a distance, including the Valparaiso earthquake in August.

The work on the Watson asteroids has progressed sufficiently to make it certain that the tables of twelve asteroids reported on a year ago will go to press in April.

The chief assistant in this work has been Miss ESTELLE GLANCY, Dr. NEWKIRK having accepted a position as Carnegie Research Assistant at the Lick Observatory in September.

Dr. CRAWFORD'S further investigation of the constant of refraction, and Dr. NEWKIRK'S tables for the reduction of measured photographic positions and his investigation of the Repsold measuring-engine are to be published in April.

A. O. LEUSCHNER, *Director.*

GENERAL NOTES.

The Work of the Harvard College Observatory.—From Professor E. C. PICKERING'S report for the year ending September 30, 1906, it appears that the work of the Harvard College Observatory continues to be mainly the quantitative and qualitative analyses by visual and photographic methods of the light of the stars. By means of photometers attached to the east equatorial at Cambridge, and of the meridian photometers at Cambridge and at Arequipa, many thousands of measures have been made during the year of the brightness of stars, with the object (*a*) of extending to stars of the thirteenth magnitude the plan of furnishing standards of magnitude on a uniform scale well distributed over the entire sky, and (*b*) of increasing our knowledge of the variable stars, especially of those of long period and of those of the *Algol* type. Miscellaneous photometric measures include the photometric measures of twenty-nine eclipses of *Jupiter's* satellites.

A large number of photographs, including spectrum plates, have been taken with the 11-inch and 8-inch Draper telescopes at Cambridge, and with the 8-inch Bache, the 13-inch Boyden, and the 24-inch Bruce telescope at Arequipa. The study of these plates has already revealed many new variable stars, stars with bright hydrogen lines, etc. Other plates have been utilized to extend the classification of stellar spectra to fainter stars on the plan of the classification given in volume XXVIII of the *Annals* The great majority of the plates are necessarily stored for future study.

Professor PICKERING again calls attention to the urgent need of the observatory of suitable fireproof buildings for housing the admirable library of the observatory, one of the finest astronomical libraries in the world, for the photographic laboratory, and for a workshop. A still greater desideratum is an addition to the staff of assistants. As Professor PICKERING says, "Perhaps the greatest return could be obtained by the employment of more assistants for the study of the unique collection of astronomical photographs. This collection now contains 189,200 photographs of the stars, and is like a library of that size with only about twenty readers."

An Interesting Variable.—The leading article in the *Astronomische Nachrichten*, No. 4148, by G. Müller and P. Kempf, gives the determination of the period and the light-curve of a new short-period variable of the δ *Cephei* type. The star is located in the constellation *Cassiopeia*, B. D. 68° 200, and has an average brightness of a little less than the sixth magnitude. Its period was found to be 1.9498 days. But the chief interest lies in the smallness of the range of brightness; this was found to be only 0.33 of a magnitude. Observations were made photometrically by both of the authors, and in order to be certain that the variations found were in reality not large accidental errors of observation they requested a third observer, Mr. K. Graff, of Hamburg, to make visual observations upon the star by Argelander's method, without, however, giving him any exact knowledge of the period to be expected. The observations of Mr. Graff completely confirmed those obtained at Potsdam, and there seems to be no doubt about the reality of the variation. When it becomes possible to differentiate with certainty a variation of a quarter of a magnitude from the accidental errors of observation, it serves to illustrate the degree of precision attainable in modern photometric work.

An Unknown Comet.—During 1905 Professor E. E. Barnard, of the Yerkes Observatory, was stationed for a time at the Solar Observatory of the Carnegie Institution on Mt. Wilson, in California, engaged in photographing the southern portions of the Milky Way with the Bruce photographic telescope of the Yerkes Observatory. After returning from the expedition a re-examination of the plates disclosed the trail of a very faint comet on each of three plates taken on July 22, 1905. These plates have been measured by Professor Barnard, giving an accurate position of the object, and the results have been published in the *Astronomische Nachrichten*, No. 4153. The comet had a right ascension of between eighteen and nineteen hours and a declination between 20° and 21° south. So far as known, it was neither seen visually by any one nor photographed at any other place. The chief interest in the object lies in the possibility of its belonging to the class of periodic comets. If such should be the case, and it should be observed at some future return to the neighborhood of the

Earth, the position determined by Mr. BARNARD might prove very valuable in fixing its orbit.

Heights of Meteors.—Under the title, "Heights of Large Meteors Observed in 1906," (*Astronomische Nachrichten*, No. 4152,) W. F. DENNING gives some interesting results obtained from the observations of ten meteors in England by himself and persons co-operating with him. The height at appearance varies between fifty-nine and eighty-nine miles, with an average value of seventy miles; the height at disappearance varies between twenty-two and fifty-six miles, with an average value of forty miles; the length of path varies between twenty-four and seventy-two miles, with an average of forty-four miles; the velocity in miles per second (given for only six) varies between fifteen and thirty, with an average value of twenty-two. It would be interesting if some one could devise a means of computing, or even roughly estimating, the mass which must be possessed by a meteor in order that it may give forth light during its flight through a certain stretch of the upper atmosphere at a given velocity.

Isaac Roberts's Celestial Photographs.—Mrs. DOROTHEA ISAAC-ROBERTS has published in the *Astronomische Nachrichten*, No. 4154, a "Preliminary Catalogue of ISAAC ROBERTS'S Collection of Photographs of Celestial Objects." This collection consists of 2,485 original negatives of stars, star-clusters, nebulæ, and other celestial objects, together with many positives on glass and on paper. Over half of the negatives were taken with a 20-inch reflector of ninety-eight inches focal length, and the balance were taken with various lenses up to five inches in diameter.

Mrs. ROBERTS proposes to make this fine collection of negatives available for the advancement of astronomical science, as may be seen from the following quotation from her article:—

"As soon as circumstances permit, a complete list of ISAAC ROBERTS'S tribute to astronomy will be published, in accordance with the wishes and instructions of the deceased.

"The number of copies of the forthcoming paper being very limited, the observatories and astronomers, official or amateur, who are specially interested in photographic astronomy will please send in their names to the address given below, early in 1907, in order that

the various parts of the complete catalogue may be sent to them in course of time.

"Positives-on-glass reproduced from the Isaac Roberts negatives will be lent for the purpose of micrometric measurements, if application be made, and provided that the documents be returned after completion of the measurements."

Mrs. ROBERTS's address is Château Rosa Bonheur, By-Thomery, Seine et Marne, France.

New Asteroids.—The number of asteroids now exceeds six hundred. Dr. J. BAUSCHINGER, Director des Astronomisches Rechen-Institut, Berlin, has recently printed, in the *Astronomische Nachrichten,* No. 4156, sets of elements for twenty-five of these small bodies discovered during 1905 and 1906.

The *Monthly Notices* of the Royal Astronomical Society for December, 1906, contains an article by Professor H. H. TURNER, "On the Possibility of Improving the Places of Reference-Stars for the Astrographic Catalogue from the Photographic Measures," which is characterized by the simplicity of method and evident practical value which mark his other contributions on the subject of photographic measures. In the process of the reduction of the measured rectangular co-ordinates of star-images on a photographic plate to the right ascension and declination of the corresponding stars, plate constants are derived with the help of the images of stars whose positions are known from meridian or other independent observations. The unavoidable errors in the positions of these stars of reference affect the plate constants and through them the positions of the previously unknown stars which result from the measures. It is the readjustment of the assumed co-ordinates of the stars of reference by a comparison of the measures of their images made on overlapping plates that is treated in this paper.

In the Oxford reductions for the astrographic catalogue it has been customary to substitute for the least-square solution of the equations for the plate constants a method in which all the equations are combined to form eight derived ones, four of which involve the constants a, b, c, and the remaining four the constants d, e, f. The four derived equations of each group are obtained by adding the equations arising from the

star-images in the four quadrants of the plate respectively. Each of the four derived equations of one group may be regarded as arising from a single fictitious star, its weight being equal to the number of stars in its quadrant. Mr. TURNER shows that if the four equations are of equal weight, and if the four fictitious stars are in the center of their respective quadrants, the four residuals after solution, either by his method or by the method of least squares, are $+ I, - I, + I, - I$, respectively, where I is the algebraic sum of the absolute terms of the four equations, two of them taken with the opposite sign This quantity I is called the "inconsistency" for the plate. It will be zero in the assumed case if the co-ordinates of the comparison-stars are correct, and the measures are affected by no errors that are not linear functions of the measured co-ordinates. Where the actual state of affairs is not too unsymmetrical it is possible therefore to write down the residuals before the solution is made and to determine, without a solution of the equations, how the residuals would be affected by arbitrary changes in the co-ordinates of the comparison-stars,—that is, in the absolute terms of the equations of condition. It would be entirely possible to make the inconsistency for a single plate zero without improving the plate constants, but any changes that materially reduce the inconsistencies of a series of overlapping plates would undoubtedly improve the plate constants of all of them.

Professor TURNER has not arrived at any general and entirely satisfactory method of accomplishing this adjustment, but the tabulation of the inconsistencies of a series of overlapping plates in "diagrammatic" form will undoubtedly lead to such adjustments, provided the symmetry of arrangement of the comparison-stars is sufficient to render applicable his theorem regarding the residuals.

The Gold Medal of the Royal Astronomical Society Awarded to Professor E. W. Brown.—The gold medal of the Royal Astronomical Society has this year been awarded to Professor ERNEST WILLIAM BROWN for his "Researches in the Lunar Theory."

On presenting the medal to Professor BROWN at the annual meeting of the society, February 8, 1907, the president, Mr. WILLIAM H. MAW, reviewed the work of the distinguished

medalist in an able and comprehensive address, from which the following is taken.

Professor BROWN is the seventh astronomer to whom the gold medal of the Royal Astronomical Society has been awarded for work in connection with the lunar theory.

In a paper entitled "Theory of the Motion of the Moon, Containing a New Calculation of the Expressions for the Coordinates for the Moon in Terms of the Time," published in volume LIII of the *Memoirs,* he has clearly stated the nature of the problem on which he has been engaged, in the following words:—

"The formation of numerical expressions deduced as a consequence of the Newtonian laws of motion and gravitation which shall represent the position of the Moon at any time may be roughly divided into three stages. As a first step, we consider each of the three bodies—the Sun, the Earth, and the Moon—as a sphere of mass equal to its actual mass, and arranged in concentric layers of equal density. The Earth (or center of mass of the Earth and Moon) is supposed to move round the Sun in a certain ideal elliptic orbit, and all disturbances of this orbit and of the Moon from any other source than the ideal Sun and Earth are neglected. The first stage constitutes nearly the whole of the problem of three bodies as far as the particular configuration of the Sun-Earth-Moon system is concerned. When this is done, we proceed to the second step, which involves the determination of the effects due to the difference between the actual and the ideal motions of the Earth and Sun, to the influence exercised by the other bodies of the solar system, and to the differences between the real and ideal arrangements of the masses of the bodies. The calculations so far may, theoretically at least, be made without any knowledge of the configuration of the system at any given time or times, beyond a general idea of the order of magnitude of certain of the constants involved. The third and final stage consists in a determination by observation of the various constants which have entered into the theory and the substitution of their values, so as to obtain numerical expressions for the co-ordinates in terms of the time."

It is the completion of the first of these stages which has primarily been the object of Professor BROWN's past labors; and as a result he has, after arduous work extending over the past fifteen years, completed the solution of the problem of three bodies for the case of Sun-Earth-Moon with an accuracy very far in excess of that attained by any of his predecessors in this line of research.

Dr. G. W. HILL, who speaks with the highest authority, has expressed the following opinion on Professor BROWN's work:—

"Much as we rightly welcome the results of Professor BROWN's devoted labors, we should be unwarranted in assuming that their employment in the lunar tables would give rise to a marked improvement in the representation of observations. A slight one indeed might be expected; but it has been evident for some time that the Moon deviated from its calculated orbit more because it is subject to irregular forces, which we have not yet the means of estimating, than because the tables are affected by slight defects in the mathematical treatment of the forces which are already recognized This circumstance in no sense diminishes the credit due to Professor BROWN's work."

By giving accurate values to the known perturbations, Professor BROWN has defined more clearly the further irregularities of which the explanation has yet to be ascertained.

The precautions taken by the medalist to secure accuracy in the final results have been most refined. In accordance with the original programme, every coefficient in longitude, latitude, and parallax which is so great as one hundredth of a second of arc, has been computed, and is regarded as accurate to at least this amount, the results being obtained to one thousandth of a second. To avoid the occurrence of errors of computation, equations of verification have been computed at every step of the work, every page of the manuscript having, on the average, not less than two test equations computed. The medalist is the first lunar theorist to use independent equations of verification, thus creating a higher degree of confidence in his results than could ever come from mere duplicate calculation.

In devising the details of his research, the medalist arranged the work so that considerable proportions could be done by computers; but as a matter of fact only one—Mr. IRA L. STERNER, of Haverford College, of whose ability and accuracy Professor BROWN speaks in the highest terms—has been employed. "The calculations have probably occupied altogether eight or nine thousand hours. There were about 13,000 multiplications of series made, containing some 400,000 separate products; the whole of the work required the writing of between some four or five millions of digits and *plus* and *minus* signs."

Professor BROWN has completed his solution of the problem of three bodies for the case of the Sun-Earth-Moon by methods involving striking elegance and originality, and showing great powers of resource. He has, however, by no means

finished his labors. As he himself has pointed out, in announcing the completion of the main problem, much still remained to be done before it was advisable to proceed to the construction of tables. On this work he is now engaged, and we may rest assured that he will continue to bring to bear upon it that energy and power of organized inquiry which have enabled him already to secure such brilliant results.

Professor BROWN is an Englishman who has long been resident in America, and who has for the past sixteen years been connected with Haverford College. That association will, however, be broken in the ensuing summer, and next autumn Professor BROWN proceeds to Yale University. It is exceedingly gratifying to know that his work on the lunar theory, which he has been able to carry on at Haverford under most favorable conditions, will not be interrupted by this change. The Yale authorities have recognized the importance of his work by arranging special facilities for its continuance, and have also most generously undertaken to provide the funds required for both the preparation and publication of the lunar tables which will form the natural outcome of Professor BROWN's labors. A. O. L.

Volume I, number I, of the *Journal of the Royal Astronomical Society of Canada* bears the date January-February, 1907. The object of the society is, in the words of the editor, "to extend and popularize the study of astronomy, astrophysics, and related branches of science." The pages of the journal are to be open to accounts of the work of amateurs as well as to technical papers. For the present the publication is to appear bi-monthly. The editors hope, however, soon to be able to issue it monthly.

Among the papers of especial interest in this first number may be mentioned the president's address, on "Progress in Astronomy and Astrophysics during 1906," and an article by J. S. PLASKETT, on "The Spectrum of *Mira Ceti.*" The "Notes from the Dominion Observatory," "Brief Astronomical Reviews," and "Astronomical News" are also worthy of mention as interesting and valuable features.

Notes from "Science."—A bill has been introduced in the legislature incorporating the New York Observatory and Nau-

tical Museum, to which reference has already been made in *Science*. It is stated in the charter that this museum is "for the purpose of encouraging and developing the maritime interests of New York City, of advancing the general knowledge of the safe navigation of the sea, of the development of harbor facilities, of prosecuting original researches in astronomy and navigation and in kindred subjects, and of affording instruction in the same."

Substantially, the museum would be placed on the same basis as the Museum of Natural History and the Metropolitan Museum of Art. The city is to provide the land and is to erect the buildings, while the corporation is to secure by private subscription not less than $300,000 for equipping the nautical museum and observatory and for prosecuting the other objects of the institution.

The French Government has made Professor SIMON NEWCOMB, U. S. N., (retired), Commander of the Legion of Honor.

Mr. E. B. McCLELLAN, third assistant at the Radcliffe Observatory, Oxford, died on January 2d, at the age of forty-five years.

Mr. H. F. NEWALL, of Trinity College, Cambridge, assistant director of the observatory, has been elected president of the Royal Astronomical Society, in succession to Mr. W. H. MAW.

Planet Markings.—At the 628th meeting of the Philosophical Society of Washington, held on February 2d, Professor NEWCOMB read a paper on "The Optical and Psychological Principles Involved in the Interpretation of the Markings on the Disks of the Planets." A short outline of the paper may be found in *Science* for March 1, 1907.

Mr. JAMES D. MADDRILL, of the University of California, Fellow in the Lick Observatory, who will take the examinations for the degree of Doctor of Philosophy in Astronomy, Physics, and Mathematics in May, has been appointed by the Superintendent of the United States Coast and Geodetic Survey to succeed Dr. SIDNEY D. TOWNLEY as observer at the International Latitude Observatory in Ukiah, and will enter upon his duties in July. A. O. L.

Obituary.—The *Astronomische Nachrichten*, No. 4145, contains a notice concerning the life and works of JEAN ABRAHAM CHRÉTIEN OUDEMANS, who died on December 14, 1906, at the age of seventy-nine years. OUDEMANS was for many years Professor of Astronomy and Director of the Observatory at the University of Utrecht. He was chiefly interested in the practical side of astronomy, and as an observer and computer held high rank among his contemporaries. He was also interested in geodetic work, and spent eighteen years in charge of the triangulation of the Dutch East Indies. The result of this work was published in six volumes under the title of "Triangulation of Java." Although Professor OUDEMANS retired from the directorship of the Utrecht Observatory in 1898, yet he did not give up his astronomical work, and only a short time before his death presented a paper at a meeting of the Royal Academy of Sciences of Amsterdam, on the "Mutual Occultations and Eclipses of the Satellites of *Jupiter* in 1908," an abstract of which will be found in these notes in our next number.

Miss AGNES MARY CLERKE, the scientific writer, died on Sunday morning, January 20th, at her residence, 68 Redcliffe Square, S. W., London, England, at the age of sixty-four. An astronomical correspondent writes with reference to Miss CLERKE:—

"During the last century two ladies only were elected honorary members of the Royal Astronomical Society—CAROLINE HERSCHEL and Mrs. SOMERVILLE. The new century soon saw fresh honorary members elected, and among them Miss AGNES CLERKE, whose last important work, 'Problems in Astrophysics,' was of such great scientific value that the Astronomical Society could no longer ignore her claims to public recognition by them. And when we say 'last important work' we must acknowledge also the outstanding merit of two earlier books, 'The System of the Stars' and 'History of Astronomy in the Nineteenth Century,' besides less important volumes, 'The HERSCHELS and Modern Astronomy,' 'Modern Cosmogonies,' and many scientific magazine articles, principally of the nature of reviews or interpretations of results, in which her keen insight into the true significance of observed physical facts was as wonderful as her fluency and command of language, so that both from the literary and scientific standpoints she must be ranked as a great scientific writer. No one writing a history of modern astronomy can fail to acknowledge the great debt owed to the masterly array of facts in her 'History.' No worker in the vast field of modern sidereal astronomy opened by the genius of HERSCHEL and greatly widened by the application of the spectroscope

to the chemical and physical problems of the universe lacked due recognition by Miss CLERKE, who performed as it seemed no other writer could have done the work of collation and interpretation of this enormous mass of new material, ever pointing the way to new fields of investigation, often by one pregnant suggestion sweeping aside a whole sheaf of tentative conjectures and indicating, if not the true line—for in many cases the truth is yet to seek—at least, a plausible and scientific line well worth pursuing. She will be missed at the meetings of the Royal Astronomical Society, at which she was a constant visitor even before her election as an honorary member, and where her clear judgment was at times called upon to determine the value of some new suggestion in the domain of celestial physics. She was not a practical astronomer in the ordinary sense; but her death, on Sunday morning, leaves a gap that will be hard to fill. She was the daughter of Mr. JOHN WILLIAM CLERKE, who died in London in 1890. Her sister, Miss C. M. CLERKE, who died a few months ago, also wrote on astronomical subjects, though in a far more humble way."—*The Times, London.*

NEW PUBLICATIONS.

BELOPOLSKY, A. Untersuchung der Ca-Linien am Sonnenrande. Mitteilungen der Nikolai-Haupt Sternwarte zu Pulkowo. Band I, No. 12. 1907. 4to. 23 pp.

BONSDORFF, I. Beobachtungen von *δ Cassiopijæ* mit dem grossen Zenitteleskop. Mitteilungen der Nikolai-Haupt Sternwarte zu Pulkowo. Band II, No. 13. 1907. 4to. 16 pp.

CANNON, ANNIE J. Second catalogue of variable stars. Cambridge: Annals of the Astronomical Observatory of Harvard College. Vol. LV, Part I. 1907. 4to. iii + 94 pp. Paper.

COOKSON, BRYAN. Determination of the mass of *Jupiter* and orbits of the satellites from observations made with the Cape heliometer. Edinburgh: Annals of the Royal Observatory, Cape of Good Hope. Vol. XII, Part II. 1906. 4to. 215 pp. Paper. 6s.

DE SITTER, W. A determination of the inclinations and nodes of the orbits of *Jupiter's* satellites, from photographic plates taken at the Royal Observatory, Cape of Good Hope. Edinburgh: Annals of the Royal Observatory, Cape of Good Hope. Vol. XII, Part III. 1906. 4to. 139 pp. Paper. 4s.

FRANZ, J. Der Mond. Leipzig: Teubner. 1906. 12mo. 132 pp.

HALM, JACOB. New reduction of Henderson's catalogue for the epoch 1840.0. Glasgow: Annals of the Royal Observatory, Edinburgh. Vol. II. 1906. 4to. xl + 104 pp. Cloth. 6s.

LOUD, F. H. Notes on the computation of logarithms. Colorado Springs: Semi-annual Bulletin of the Colorado College Observatory. 1907. 8vo. 19 pp.

LUNT, JOSEPH. The spectra of silicon, fluorine, and oxygen. Edinburgh: Annals of the Royal Observatory, Cape of Good Hope. Vol. X, Part II—Spectroscopic Researches. 1906. 4to. 43 pp. Paper. 3s.

MÜLLER, G., und KEMPF, P. Photometrische Durchmusterung des Nördlichen Himmels, enthaltend die Gröszen und Farben aller Sterne der B. D. bis zur Grösze 7.5. Generalkatolog. Potsdam: Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Band XVII. 1907. 4to. xxxv + 293 pp. Boards. 18m.

OUDEMANS, J. A. C. Mutual occultations and eclipses of the satellites of *Jupiter* in 1908. Parts I and II. Reprinted from the Proceedings of the Amsterdam Academy of Sciences, 1906. 32 and 15 pp.

WEINEK, L. Astronomische Beobachtungen an der K. K. Sternwarte zu Prag. in den Jahren 1900-1904. Prag. 1907. 4to. vi + 106 pp. Plates.

WOOD, R. W. Physical optics. New York: Macmillan Co. 1907. 8vo. 546 pp. Cloth, $3.50.

Positions of *Phœbe,* 1898-1904. Cambridge: Annals of the Astronomical Observatory of Harvard College. Vol. LX, No. III. 4to. 40 pp. Paper.

Eclipses of *Jupiter's* satellites, 1878-1903. Cambridge: Annals of the Astronomical Observatory of Harvard College. Vol. LII, Part I. 4to. iii + 148 pp. Paper.

The Nautical Almanac for 1910. Edinburgh: 1906. 8vo. xiii + 602 + 44 pp. Paper, 2s 6d.

Catalogue of stars for the equinox 1900.0, from observations made at the Royal Observatory, Cape of Good Hope, during the years 1900-1904. Edinburgh: 1906. 4to. xiii + 123 pp. Cloth, 4s 6d.

A catalogue of 8,560 astrographic standard stars between declinations —40° and —52° for the equinox 1900.0, from observations made at the Royal Observatory, Cape of Good Hope, during the years 1896-1899 (with three appendices). Edinburgh. 1906. 4to. lix + 403 pp. Cloth.

Results of meridian observations of stars made at the Royal Observatory, Cape of Good Hope, in the years 1900 to 1904. Edinburgh. 1906. 4to. xxx + 274 pp. Cloth.

Astronomical and magnetical and meteorlogical observations made at the Royal Observatory, Greenwich, in the year 1904. Edinburgh. 1906. 4to. cxlvi + (334) + (*96*) + 155 + *97* + *lviii* + (cxliii) + 9 + 23 + vii + 24 pp. Cloth.

Minutes of the Meeting of the Board of Directors held on March 30, 1907, at 7:30 P.M.

President Leuschner presided. A quorum was present.

The following resolution was adopted:—

Resolved, That the Publication Committee be authorized to expend $600 for *Publications* to the end of the current calendar year.

Adjourned.

Minutes of the Nineteenth Annual Meeting of the Astronomical Society of the Pacific, held in the Law Offices of Cushing, Grant & Cushing, 1652 O'Farrell Street, March 30, 1907, at 8 P.M.

The meeting was called to order by President Leuschner. A quorum was present. The minutes of the last meeting were approved.

The Committee on Nominations reported a list of names proposed for election as Directors and Committee on Publication. Messrs. Baird and Cornish were appointed as tellers. The polls were open from 8:15 to 9 P.M., and the following persons were duly elected to serve for the ensuing year:—

For Directors: R. G. Aitken, A. H. Babcock, Chas. Burckhalter, Wm. H. Crocker, W. W. Campbell, Chas. S. Cushing, George E. Hale, S. D. Townley, F. R. Ziel, R. T. Crawford, D. S. Richardson.

For Committee on Publication: R. G. Aitken, S. D. Townley, B. L. Newkirk.

Report of the Donohoe Comet-Medal Committee for the Year 1906.

The following comets were discovered during the year 1906:—

Comet *a* 1906, an unexpected comet, was discovered by Professor W. R. Brooks at Geneva, New York, on January 26th.

Comet *b* 1906, an unexpected comet, was discovered by Dr. A. Kopff at Heidelberg, Germany, on March 3d.

Comet *c* 1906, an unexpected comet, was discovered by D. Ross at Melbourne, Australia, on March 17th.

Comet *d* 1906, Finlay's periodic comet, was re-discovered by Dr. A. Kopff at Heidelberg, Germany, on July 16th.

Comet *e* 1906, an unexpected comet, was discovered by Dr. A. Kopff at Heidelberg, Germany, on August 22d.

Comet *f* 1906, Holmes's periodic comet, was re-discovered by Professor Max Wolf at Heidelberg, Germany, on August 28th.

Comet *g* 1906, an unexpected comet, was discovered by Professor H. Thiele at Copenhagen, Denmark, on November 10th.

Comet *h* 1906, an unexpected comet, was discovered by Rev. J. H. Metcalf at Taunton, Massachusetts, on November 14th.

The Donohoe Comet-Medal of the Astronomical Society of the Pacific has been awarded to the discoverers of Comets *a*, *b*, *c*, *e*, *g*, and *h*.

It should be noted that Comets *b*, *d*, *e*, *f*, and *h* 1906 were discovered by photographic methods.

Respectfully submitted,

W. W. Campbell,
Chas. Burckhalter,
C. D. Perrine,
} *Committee.*

The Treasurer submitted his Annual Report, as follows:—

Annual Statement of the Receipts and Expenditures of the Astronomical Society of the Pacific for the Fiscal Year Ending March 30, 1907.

GENERAL FUND.

Receipts.

1906. April 1st. Balance				$ 36 11
Received from—				
Dues for 1906 and previous years		$191 05		
Dues for 1907		555 40		
			$ 746 45	
Life membership fee			50 00	
Sales of *Publications*			39 00	
Legacy, Estate of Morris Reiman		500 00		
Less inheritance tax	$18 90			
Less lawyer's fees	50 00			
		68 90	431 10	
Life Membership Fund (interest)			72 04	
Life Membership Fund (loan)			276 25	
John Dolbeer Fund (interest)			219 47	
Wm. Alvord Fund (interest)			180 84	
London & Lancashire Fire Insurance Company, for loss under Policy No. 4823220, on claim of $2,000			1,900 00	
				$3,915 15
				$3,951 26
Less transfer to Life Membership Fund (fee)			$ 50 00	
Less transfer to Montgomery Library Fund (fire insurance loss)			1,900 00	
				1,950 00
				$2,001 26

Expenditures.

For *Publications*—Printing Nos. 106 to 112	$1,115 75		
Illustrations	9 10		
		$1,124 85	
Reprints	$36 50		
Stationery and printing	71 20		
Postages	60 00		
Rent	.. ..		
Salary Secretary-Treasurer	180 00		
Expressages	18 71		
Janitor	11 90		
Gas	20		
Insurance premiums	17 60		
Fee re claim vs. Rhine-Moselle Fire Insurance Co.	5 00		
Lantern at lecture	8 00		
Engrossing	2 25		
Notary fees	3 50		
Rent safe deposit box	5 00		
Bank exchanges	30		
		420 16	
			1,545 01
1907. March 30th. Balance			$ 456 25

Dues outstanding—

For 1906	$100 00
For 1907	310 00
	$410 00

LIFE MEMBERSHIP FUND.

1906.	April 1st. Balance		$1,953 95
	Received from General Fund (fee)		50 00
	Interest		72 04
			$2,075 99
	Less transfer to General Fund (interest)	$ 72 04	
	Less transfer to General Fund (loan)	276 25	
			348 29
1907.	March 30th. Balance		$1,727 70

ALEXANDER MONTGOMERY LIBRARY FUND.

1906.	April 1st. Balance	$1,533 87
	Received from London & Lancashire Fire Insurance Company, on claim of $2,000	1,900 00
	Interest	67 50
1907.	March 30th. Balance	$3,501 37

DONOHOE COMET-MEDAL FUND.

1906.	April 1st. Balance	$ 766 57
	Interest	28 94
		$ 795 51
	Less engraving medals Nos. 53, 54, 55, and postage	2 85
1907.	March 30th. Balance	$ 792 66

BRUCE MEDAL FUND.

1906.	April 1st. Balance	$2,669 04
	Interest	122 61
1907.	March 30th. Balance	$2,791 65

JOHN DOLBEER FUND.

1906.	April 1st. Balance	$5,000 00
	Interest	219 47
		$5,219 47
	Less interest expended for *Publications* (see General Fund)	219 47
1907.	March 30th. Balance	$5,000 00

WILLIAM ALVORD FUND.

1906.	April 1st. Balance	$5,000 00
	Interest	180 84
		$5,180 84
	Less interest expended for *Publications* (see General Fund)	180 84
1907.	March 30th. Balance	$5,000 00

FUNDS.

Balances as follows:—

General Fund.

With Donohoe-Kelly Banking Company................		$ 456 25

Life Membership Fund.

With German Savings & Loan Society................	$ 727 70	
South Pacific Coast Railway Co. 1st Mortgage 4 per cent guaranteed (by S. P. Co.) $1,000, Gold Bond No. 3406	1,000 00	
(Interest Jan. and July; principal due July 1, 1937.)	———	1,727 70

Alexander Montgomery Library Fund.

With Security Savings Bank..........................	$1,377 35	
Oakland Transit Consolidated, 1st consolidated Mortgage, 5 per cent, $1,000 Gold Bond No. 4328............	1,040 00	
(Interest Jan. and July; principal due July 1, 1932.)		
Sunset Telephone and Telegraph Company, consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 641......	1,084 02	
(Interest April and Oct.; principal due Oct. 1, 1929.)	———	3,501 37

Donohoe Comet-Medal Fund.

With San Francisco Savings Union..................		792 66

Bruce Medal Fund.

With Mutual Savings Bank..........................	$ 801 93	
Bay Counties Power Company, 1st consolidated Mortgage 5 per cent, $1,000 Sinking Fund Gold Bond No. 1636..	1,012 50	
(Interest March and Sept.; principal due Sept. 1, 1930.)		
The Edison Electric Company, Los Angeles, 1st and Refunding Mortgage 5 per cent, $1,000 Gold Bond No. 168	977 22	
(Interest March and Sept.; principal due Sept. 1, 1922.)	———	2,791 65

John Dolbeer Fund.

With Union Trust Company..........................	$ 970 28	
South Pacific Coast Railway Company, 1st Mortgage 4 per cent guaranteed (by S. P. Co.), $1,000 Gold Bond No. 3407	1,000 00	
(Interest Jan. and July; principal due July 1, 1937.)		
Oakland Transit Consolidated, 1st consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 4329..............	1,040 00	
(Interest Jan. and July; principal due July 1, 1932.)		
Bay Counties Power Company, 1st consolidated Mortgage 5 per cent, $1,000 Sinking Fund Gold Bond No. 1637.	1,012 50	
(Interest March and Sept.; principal due Sept. 1, 1930.)		
The Edison Electric Company, Los Angeles, 1st and Refunding Mortgage 5 per cent, $1,000 Gold Bond No. 169	977 22	
(Interest March and Sept.; principal due Sept. 1, 1922.)	———	5,000 00

William Alvord Fund.

With Humboldt Savings Bank........................	$ 331 94	
With Savings & Loan Society........................	1,463 50	
Sunset Telephone and Telegraph Company, consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 656, and $1,000 Gold Bond No. 657.........................	2,168 06	
(Interest April and Oct.; principal due Oct. 1, 1929.)		
Contra Costa Water Company, 5 per cent $1,000 Gold Bond No. 87	1,036 50	
(Interest Jan. and July; principal due Jan. 1, 1915.)	———	5,000 00
		$19,269 63

San Francisco, March 30, 1907.

Examined and found correct.

Charles S. Cushing, } *Auditing*
B. A. Baird, } *Committee.*

F. R. Ziel, *Treasurer.*

The report was, on motion, accepted and filed.

The President, in an informal address, briefly reviewed the condition of the Society, and then proceeded to speak on the results of statistics on the eccentricities of comet orbits, an extract of which appears in this number of the *Publications*.

Professor AITKEN gave an interesting talk on "Double Stars."

The thanks of the Society were returned to Messrs. CUSHING, GRANT & CUSHING, for the use of their rooms.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD MARCH 30, 1907, AT 10 P.M.

The new Board of Directors was called to order by President LEUSCHNER. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers for the ensuing year, the following officers, having received a majority of the votes cast, were duly elected:—

President: Mr. CHAS. S CUSHING.

First Vice-President: Mr. A. H. BABCOCK.

Second Vice-President: Mr. W. W. CAMPBELL.

Third Vice-President: Mr. GEO. E. HALE.

Secretary: Mr. R. T. CRAWFORD.

Treasurer: Mr. F. R. ZIEL.

Committee on the Comet-Medal: Messrs. W. W. CAMPBELL (*ex officio*), CHAS. BURCKHALTER, C. D. PERRINE.

Library Committee: Messrs. CRAWFORD, IRVING, TOWNLEY.

Mr. CRAWFORD was appointed Librarian.

The President was authorized to appoint the members of the Finance Committee, and made the following selections:—

Finance Committee: D. S. RICHARDSON (Chairman), WM. H. CROCKER, CHAS. BURCKHALTER.

The Committee on Publication is composed of Messrs. R. G. AITKEN, S. D. TOWNLEY, B. L. NEWKIRK.

The following resolution was adopted:—

WHEREAS, Mr. F. R. ZIEL retires from the office of Secretary of the Society after fifteen consecutive years of service;

Resolved, That the Directors hereby express their hearty thanks to Mr. ZIEL for the disinterested fidelity and the great efficiency of his services to the Society.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Chas. S. Cushing . . . . *President*
Mr. A. H. Babcock . . . . *First Vice-President*
Mr. W. W. Campbell . . . . *Second Vice-President*
Mr. Geo. E. Hale . . . . *Third Vice-President*
Mr. R. T. Crawford (Students' Observatory, Berkeley) . . . . *Secretary*
Mr. F. R. Ziel . . . . *Treasurer*

Board of Directors—Messrs. Aitken, Babcock, Burckhalter, Campbell, Crocker, Crawford, Cushing, Hale, Richardson, Townley, Ziel.

Finance Committee—Messrs. Richardson, Crocker, Burckhalter.

Committee on Publication—Messrs. Aitken, Townley, Newkirk.

Library Committee—Messrs. Crawford, Irving, Townley.

Committee on the Comet Medal—Messrs. Campbell (ex-officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

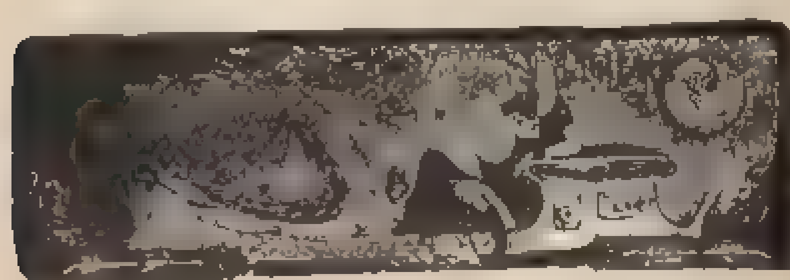
It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY
(February, April, June, August, October, December.)



INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.
(LOOKING SOUTH.)

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XIX. San Francisco, California, June 10, 1907. No. 114.

ECLIPSES AND TRANSITS OF THE SATELLITES OF *SATURN* OCCURRING IN THE YEAR 1907.

By Hermann Struve.

In the present year the cycle of eclipses and transits of the satellites of *Saturn* extends over all satellites, including *Titan*, and it is to be hoped that this very favorable opportunity of observing these interesting phenomena will not be lost. I have therefore computed the approximate times and places of the eclipses and transits for every day from June 20, 1907, to January 17, 1908.

In the following tables are first collected the data for the eclipses and transits of *Titan*, phenomena which can be observed also with smaller instruments. It would be of particular interest to observe the eclipses of *Titan* with photometers, the long duration of the appearances of *Titan* giving sufficient time for photometric comparisons. In the case of *Titan* it happens that both phenomena, the disappearance and the reappearance, are visible on the same day from the Earth. The times given for the eclipses of *Titan* are the moments when the center of the satellite passes the shadow-cone from the center of the Sun. For the transits of the shadow and of the disk of *Titan* the times of their crossing the minor axis of the planet are computed, and also the semi-duration of the transits, giving the approximate times of their ingress and egress on the disk of *Saturn*. It is to be understood that the predicted times depend greatly on the assumed values of the diameters of the planet and may deviate several minutes from the truth. Careful estimations of the times when the shadow on the disk of *Titan* is first or last seen on the planet will be very valuable.

The tables of the eclipses of the other satellites are arranged in the same manner as in the preceding year.[1] For these satellites only the disappearances are visible before opposition and only the reappearances after opposition. The first column contains the day of the month, the second the eclipsed satellite, the third the Greenwich time of the disappearance or reappearance, the last column, headed *s* and *p*, the geocentric place of the satellite at the time of his eclipse,—i. e. the distance of the satellite from the limb of the planet, and the position-angle, counted from the north point of the minor axis of the disk. The duration of the appearances, occurring this year nearly centrally, may be, in the case of *Rhea* several minutes, in the case of *Tethys* and *Dione* about one minute, in the case of *Mimas* and *Enceladus* only a few seconds. The attention of astronomers who are in possession of powerful instruments is particularly directed to these phenomena. On account of the disappearance of the rings before July 26th and after October 4th, and of their minuteness in the interval between those dates, it seems however very likely that in this year also instruments of moderate size can take part in these interesting observations.

It would be of great value also to ascertain the times of disappearance and reappearance of the rings by watching the planet carefully some days before and after the predicted dates. The observation of the first disappearance, on April 17th, will escape on account of the nearness of the Sun, but the reappearances of July 26th and January 7th and the disappearance of October 4th can be well observed.

Finally are added the approximate Greenwich times, when the shadows of the satellites *Tethys*, *Dione*, *Rhea* cross the minor axis of the disk, together with their distances from the center of the disk at the time of conjunction.

In the present opposition *Hyperion* also will be eclipsed at the times of his superior conjunction; but as it is doubtful whether these eclipses can be observed with sufficient accuracy I have not thought it worth while to calculate their times.

In the preparation of the following tables I was kindly assisted by Dr. P. GUTHERICK.

ROYAL OBSERVATORY, BERLIN, March, 1907

[1] See these *Publications*, Vol. XVIII, p. 203.

DISAPPEARANCE AND REAPPEARANCE OF THE RINGS OF *SATURN*.

1907. April 17.	Disappearance.	The Earth in the plane of the rings.
July 26.	Reappearance.	The Sun in the plane of the rings.
October 4.	Disappearance.	The Earth in the plane of the rings.
1908. January 7.	Reappearance.	The Earth in the plane of the rings.

ECLIPSES OF *TITAN*.

s and *p* denote the geocentric place of *Titan* at the time of its eclipse, i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the west or to the east.

			Gr. M. T.	*s*	*p*	
1907.	June 7	Disapp.	1h 23m	15″.8	104°	West.
	June 7	Reapp.	7 0	1 .4	128	
	June 23	Disapp.	0 27	17 .1	105	
	June 23	Reapp.	6 14	2 .0	130	
	July 8	Disapp.	23 33	17 .0	106	
	July 9	Reapp.	5 26	1 .5	134	
	July 24	Disapp.	22 40	15 .5	106	
	July 25	Reapp.	4 37	0 .0	141	
	Aug. 9	Disapp.	21 49	12 .5	105	
	Aug. 25	Disapp.	21 0	8 .0	104	
	Sept. 10	Disapp.	20 13	2 .6	101	
	Sept. 27	Reapp.	1 9	2 .2	91	East
	Oct. 13	Reapp.	0 15	6 .9	85	
	Oct. 28	Reapp.	23 19	10 .6	82	
	Nov. 13	Reapp.	22 22	13 .0	81	
	Nov. 29	Disapp.	16 56	0 .9	71	
	Nov. 29	Reapp.	21 22	13 .8	82	
	Dec. 15	Disapp.	16 27	1 .9	77	
	Dec. 15	Reapp.	20 19	13 .0	83	
	Dec. 31	Disapp.	16 3	2 .0	84	
	Dec. 31	Reapp.	19 9	10 .8	87	
1908.	Jan. 16	Disapp.	15 51	1 .9	93	
	Jan. 16	Reapp.	17 48	7 .3	92	

SHADOW OF *TITAN* AND DISK OF *TITAN*.

Crossing the minor axis of the planet at the distance *y* from the center.

			Gr. M. T.	*y*		Semi-duration of transit.
1907.	June 15	Shadow	9h 56m	1″.9	South	3h.0
	June 15	Disk	16 2	6 .4	North	1 .7
	July 1	Shadow	9 5	1 .2	South	3 .0
	July 1	Disk	15 7	7 .0	North	1 .5
	July 17	Shadow	8 16	0 .5	South	3 .0
	July 17	Disk	13 48	7 .0	North	1 .6
	Aug. 2	Shadow	7 30	0 .2	North	3 .0
	Aug. 2	Disk	12 6	6 .3	North	2 .0
	Aug. 18	Shadow	6 43	0 .9	North	3 .0
	Aug. 18	Disk	9 51	5 .0	North	2 .5

			Gr. M. T.	y		Semi-duration of transit.
1907.	Sept. 3	Shadow	$5^h\ 59^m$	1″.6	North	$3^h.0$
	Sept. 3	Disk	7 42	3 .2	North	2 .8
	Sept. 19	Disk	5 14	1 .3	North	3 .0
	Sept. 19	Shadow	5 15	2 .3	North	2 .9
	Oct. 5	Disk	2 48	0 .7	South	3 .0
	Oct. 5	Shadow	4 33	2 .9	North	2 .9
	Oct. 21	Disk	0 31	2 .2	South	2 .9
	Oct. 21	Shadow	3 49	3 .6	North	2 .8
	Nov. 5	Disk	22 32	3 .1	South	2 .8
	Nov. 6	Shadow	3 5	4 .3	North	2 .6
	Nov. 21	Disk	20 46	3 .4	South	2 .8
	Nov. 22	Shadow	2 21	4 .9	North	2 .4
	Dec. 7	Disk	19 47	2 .9	South	2 .8
	Dec. 8	Shadow	1 34	5 .5	North	2 .1
	Dec. 23	Disk	19 2	1 .8	South	2 .9
	Dec. 24	Shadow	0 48	6 .2	North	1 .8
1908.	Jan. 8	Disk	18 42	0 .2	South	3 .0
	Jan. 8	Shadow	23 59	6 .8	North	1 .2
	Jan. 24	Disk	18 42	1 .7	North	3 .0
	Jan. 24	Shadow?	23 6	7 .4	North	?

ECLIPSES OF THE INNER SATELLITES OF *SATURN*, 1907.

DISAPPEARANCE BEFORE OPPOSITION.

s and p denote the geocentric place of the satellite at the time of its disappearance, i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the west.

		Gr. M. T.	s	p
June 20	Mi	$0^h\ 42^m$	2″.3	91° West
	Rh	4 2	7 .2	100
	Di	4 5	5 .2	99
	En	8 36	3 .2	96
	Te	20 29	3 .9	94
	Mi	23 19	2 .3	91
21	En	17 29	3 .2	96
	Mi	21 56	2 .3	91
22	Te	17 48	3 .9	94
	Mi	20 33	2 .3	91
	Di	21 46	5 .2	99
23	Ti D	0 27	17 .1	105
	En	2 22	3 .2	96
	Ti R	6 14	2 .0	130
	Mi	19 10	2 .3	91
24	En	11 15	3 .2	96
	Te	15 7	3 .9	94
	Rh	16 28	7 .3	100
	Mi	17 47	2 .3	91
25	Di	15 28	5 .2	99
	Mi	16 25	2 .3	91
	En	20 9	3 .2	96
26	Te	12 25	3 .9	94
	Mi	15 2	2 .3	91
27	En	5 2	3 .2	96
	Mi	13 39	2 .3	91
28	Di	9 10	5 .2	99
June 28	Te	$9^h\ 44^m$	3″.9	94° W
	Mi	12 16	2 .2	91
	En	13 55	3 .2	96
29	Rh	4 55	7 .4	100
	Mi	10 53	2 .2	91
	En	22 48	3 .2	96
30	Te	7 2	3 .8	94
	Mi	9 30	2 .2	91
July 1	Di	2 51	5 .2	99
	En	7 41	3 .1	96
	Mi	8 7	2 .2	91
2	Te	4 21	3 .8	94
	Mi	6 44	2 .2	91
	En	16 34	3 .1	96
3	Mi	5 21	2 .2	91
	Rh	17 22	7 .4	101
	Di	20 33	5 .2	99
4	En	1 27	3 .1	96
	Te	1 39	3 .8	94
	Mi	3 58	2 .2	91
5	Mi	2 36	2 .2	92
	En	10 21	3 .1	96
	Te	22 58	3 .8	94
6	Mi	1 13	2 .2	92
	Di	14 15	5 .1	99
	En	19 14	3 .1	96
	Mi	23 50	2 .2	92

		Gr. M. T.		s	p
July 7	Te	20h	17m	3″.8	94° West
	Mi	22	27	2.2	92
8	En	4	7	3.1	96
	Rh	5	49	7.3	101
	Mi	21	4	2.2	92
	Ti D	23	33	17.0	106
9	Ti R	5	26	1.5	134
	Di	7	56	5.1	99
	En	13	0	3.1	96
	Te	17	35	3.8	94
	Mi	19	41	2.2	92
10	Mi	18	18	2.2	92
	En	21	53	3.0	96
11	Te	14	54	3.7	94
	Mi	16	55	2.2	92
12	Di	1	38	5.1	99
	En	6	47	3.0	96
	Mi	15	33	2.2	92
	Rh	18	16	7.2	101
13	Te	12	12	3.7	94
	Mi	14	10	2.2	92
	En	15	40	3.0	96
14	Mi	12	47	2.2	92
	Di	19	20	5.0	99
15	En	0	33	3.0	96
	Te	9	31	3.7	94
	Mi	11	24	2.1	92
16	En	9	26	3.0	96
	Mi	10	1	2.1	92
17	Rh	6	43	7.0	101
	Te	6	50	3.7	94
	Mi	8	38	2.1	92
	Di	13	1	5.0	99
	En	18	19	3.0	96
18	Mi	7	15	2.1	92
19	En	3	12	2.9	96
	Te	4	8	3.6	94
	Mi	5	52	2.1	92
20	Mi	4	30	2.1	92
	Di	6	43	4.9	99
	En	12	6	2.9	96
21	Te	1	27	3.6	94
	Mi	3	7	2.1	92
	Rh	19	10	6.7	100
	En	20	59	2.9	96
22	Mi	1	44	2.0	92
	Te	22	45	3.5	94
23	Mi	0	21	2.0	92
	Di	0	25	4.8	99
	En	5	52	2.8	96
	Mi	22	58	2.0	92
24	En	14	45	2.8	96
	Te	20	4	3.4	94
	Mi	21	35	2.0	92
	Ti D	22	40	15.5	106
25	Ti R	4	37	0.0	141
	Di	18	7	4.7	99
	Mi	20	12	2.0	92
	En	23	38	2.8	96
26	Rh	7	37	6.4	100
	Te	17	23	3.3	94

		Gr. M. T.		s	p
July 26	Mi	18h	50m	1″.9	92° West
27	En	8	31	2.7	96
	Mi	17	27	1.9	92
28	Di	11	48	4.6	99
	Te	14	41	3.3	94
	Mi	16	4	1.9	92
	En	17	25	2.7	96
29	Mi	14	41	1.9	92
30	En	2	18	2.7	96
	Te	12	0	3.2	94
	Mi	13	18	1.8	92
	Rh	20	4	6.2	100
31	Di	5	30	4.5	99
	En	11	11	2.6	96
	Mi	11	55	1.8	92
Aug. 1	Te	9	19	3.1	94
	Mi	10	33	1.8	92
	En	20	4	2.6	96
2	Mi	9	10	1.8	92
	Di	23	12	4.3	99
3	En	5	57	2.5	96
	Te	6	37	3.0	94
	Mi	7	47	1.8	92
4	Mi	6	24	1.7	92
	Rh	8	32	5.8	100
	En	13	51	2.5	96
5	Te	3	56	2.9	94
	Mi	5	1	1.7	92
	Di	16	54	4.1	98
	En	22	44	2.4	96
6	Mi	3	39	1.7	92
7	Te	1	15	2.8	94
	Mi	2	16	1.7	92
	En	7	37	2.3	96
8	Mi	0	53	1.7	92
	Di	10	36	3.9	98
	En	16	30	2.3	96
	Rh	20	59	5.4	100
	Te	22	33	2.8	93
	Mi	23	30	1.6	92
9	Ti	21	49	12.5	105
	Mi	22	7	1.6	92
10	En	1	24	2.2	96
	Te	19	52	2.7	93
	Mi	20	45	1.6	92
11	Di	4	17	3.7	98
	En	10	17	2.2	95
	Mi	19	22	1.5	92
12	Te	17	11	2.6	93
	Mi	17	59	1.5	92
	En	19	10	2.2	95
13	Rh	9	26	4.9	99
	Mi	16	36	1.5	92
	Di	21	59	3.5	98
14	En	4	3	2.1	95
	Te	14	29	2.5	93
	Mi	15	13	1.5	92
15	En	12	56	2.0	95
	Mi	13	51	1.4	92
16	Te	11	48	2.3	93
	Mi	12	28	1.4	92

		Gr. M. T.	s	p
Aug. 16	Di	15h 41m	3″.3	98° West
	En	21 50	1 .9	95
17	Mi	11 5	1 .4	92
	Rh	21 53	4 .5	99
18	En	6 43	1 .8	95
	Te	9 7	2 .2	93
	Mi	9 42	1 .3	92
19	Mi	8 19	1 .3	92
	Di	9 23	3 .0	98
	En	15 36	1 .8	95
20	Te	6 25	2 .1	92
	Mi	6 57	1 .3	92
21	En	0 29	1 .7	95
	Mi	5 34	1 .3	92
22	Di	3 5	2 .8	97
	Te	3 44	2 .0	92
	Mi	4 11	1 .2	92
	En	9 23	1 .7	95
	Rh	10 21	3 .9	99
23	Mi	2 48	1 .2	92
	En	18 16	1 .6	95
24	Te	1 3	1 .9	92
	Mi	1 26	1 .2	92
	Di	20 47	2 .5	97
25	Mi	0 3	1 .1	92
	En	3 9	1 .5	95
	Ti	21 0	8 .0	104
	Te	22 22	1 .8	91
	Mi	22 40	1 .1	92
26	En	12 2	1 .4	95
	Mi	21 17	1 .1	92
	Rh	22 48	3 .4	98
27	Di	14 29	2 .3	97
	Te	19 40	1 .6	91
	Mi	19 55	1 .0	92
	En	20 56	1 .3	95
28	Mi	18 32	0 .9	92
29	En	5 49	1 .2	94
	Te	16 59	1 .5	91
	Mi	17 9	0 .9	92
30	Di	8 11	2 .0	96
	En	14 42	1 .2	94
	Mi	15 46	0 .8	92
31	Rh	11 16	2 .7	98
	Te	14 18	1 .4	91
	Mi	14 24	0 .8	92
	En	23 35	1 .1	94
Sept. 1	Mi	13 1	0 .7	92
2	Di	1 53	1 .8	96
	En	8 29	1 .0	94

		Gr. M. T.	s	p
Sept. 2	Te	11h 37m	1″.3	91° We
	Mi	11 38	0 .7	92
3	Mi	10 15	0 .7	92
	En	17 22	0 .9	94
4	Mi	8 53	0 .6	92
	Te	8 55	1 .1	90
	Di	19 35	1 .5	96
	Rh	23 43	2 .2	97
5	En	2 15	0 .8	94
	Mi	7 30	0 .6	92
6	Mi	6 7	0 .5	92
	Te	6 14	1 .0	90
	En	11 9	0 .7	94
7	Mi	4 44	0 .5	92
	Di	13 17	1 .2	95
	En	20 2	0 .7	94
8	Mi	3 22	0 .5	92
	Te	3 33	0 .8	90
9	Mi	1 59	0 .4	92
	En	4 55	0 .6	93
	Rh	12 11	1 .6	96
10	Mi	0 36	0 .4	92
	Te	0 52	0 .7	90
	Di	6 59	0 .9	95
	En	13 49	0 .5	93
	Ti	20 13	2 .6	101
	Mi	23 14	0 .3	92
11	Mi	21 51	0 .3	92
	Te	22 .11	0 .5	89
	En	22 42	0 .4	93
12	Mi	20 28	0 .2	92
13	Di	0 41	0 .6	94
	En	7 35	0 .3	93
	Mi	19 5	0 .2	92
	Te	19 30	0 .3	89
14	Rh	0 39	0 .7	95
	En	16 29	0 .2	92
	Mi	17 43	0 .1	92
15	Mi	16 20	0 .1	92
	Te	16 48	0 .2	89
	Di	18 23	0 .3	94
16	En	1 22	0 .1	92
	Mi	14 57	0 .0	92
17	En	10 15	0 .1	92
	Mi	13 35	0 .0	92
	Te	14 7	0 .1	89
18	Di	12 5	0 .1	93
	Mi	12 12	0 .0	92
	Rh	13 6	0 .1	94
	En	19 9	0 .0	92

REAPPEARANCE AFTER OPPOSITION.

s and *p* denote the geocentric place of the satellite at the time of its reappearance, i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the east.

		Gr. M. T.	s	p
Sept. 17	Mi	15h 55m	0″.0	95° East
	Te	17 6	0 .0	90
18	Mi	14 32	0 .0	95
	Di	15 25	0 .0	93
	Rh	17 3	0 .0	93

		Gr. M. T.	s	p
Sept. 18	En	21h 49m	0″.0	92° Ea
19	Mi	13 9	0 .0	95
	Te	14 25	0 .0	90
20	En	6 43	0 .1	92
	Mi	11 47	0 .1	95

		Gr. M. T.		s	p
Sept. 21	Di	9h	7m	0."2	92° East
	Mi	10	24	0 .1	95
	Te	11	44	0 .1	90
	En	15	36	0 .2	92
22	Mi	9	1	0 .2	95
23	En	0	29	0 .3	91
	Rh	5	31	0 .6	92
	Mi	7	39	0 .2	95
	Te	9	3	0 .3	89
24	Di	2	50	0 .4	92
	Mi	6	16	0 .2	94
	En	9	23	0 .4	91
25	Mi	4	53	0 .3	94
	Te	6	21	0 .5	89
	En	18	16	0 .4	91
26	Mi	3	30	0 .3	94
	Di	20	32	0 .6	91
27	Ti	1	9	2 .2	91
	Mi	2	8	0 .4	94
	En	3	9	0 .5	91
	Te	3	40	0 .6	89
	Rh	17	58	1 .2	91
28	Mi	0	45	0 .4	94
	En	12	3	0 .6	91
	Mi	23	22	0 .4	94
29	Te	0	59	0 .8	89
	Di	14	14	0 .9	91
	En	20	56	0 .7	91
	Mi	22	0	0 .4	94
30	Mi	20	37	0 .5	94
	Te	22	18	0 .8	89
Oct. 1	En	5	50	0 .8	91
	Mi	19	14	0 .5	94
2	Rh	6	26	1 .8	90
	Di	7	56	1 .2	90
	En	14	43	0 .8	91
	Mi	17	52	0 .6	94
	Te	19	37	1 .0	88
3	Mi	16	29	0 .6	94
	En	23	36	0 .9	90
4	Mi	15	6	0 .6	94
	Te	16	56	1 .1	88
5	Di	1	38	1 .4	90
	En	8	30	0 .9	90
	Mi	13	43	0 .7	94
6	Mi	12	21	0 .7	94
	Te	14	15	1 .3	88
	En	17	23	1 .0	90
	Rh	18	53	2 .3	89
7	Mi	10	58	0 .8	94
	Di	19	20	1 .6	89
8	En	2	16	1 .1	90
	Mi	9	35	0 .8	94
	Te	11	34	1 .4	88
9	Mi	8	13	0 .8	94
	En	11	10	1 .1	90
10	Mi	6	50	0 .9	94
	Te	8	53	1 .5	88
	Di	13	2	1 .9	89
	En	20	3	1 .2	90
11	Mi	5	27	0 .9	93
Oct. 11	Rh	7h	21m	2".9	88° East
12	Mi	4	5	0 .9	93
	En	4	57	1 .3	90
	Te	6	12	1 .7	88
13	Ti	0	15	6 .9	85
	Mi	2	42	1 .0	93
	Di	6	44	2 .2	88
	En	13	50	1 .3	89
14	Mi	1	19	1 .0	93
	Te	3	31	1 .8	87
	En	22	43	1 .4	89
	Mi	23	56	1 .0	93
15	Rh	19	49	3 .4	88
	Mi	22	34	1 .0	93
16	Di	0	26	2 .4	88
	Te	0	50	2 .0	87
	En	7	37	1 .5	89
	Mi	21	11	1 .0	93
17	En	16	30	1 .6	89
	Mi	19	48	1 .1	93
	Te	22	9	2 .0	87
18	Di	18	8	2 .6	88
	Mi	18	26	1 .1	93
19	En	1	24	1 .6	89
	Mi	17	3	1 .1	93
	Te	19	28	2 .2	87
20	Rh	8	16	3 .9	87
	En	10	17	1 .7	89
	Mi	15	40	1 .2	93
21	Di	11	51	2 .8	88
	Mi	14	18	1 .2	93
	Te	16	47	2 .3	87
	En	19	11	1 .7	89
22	Mi	12	55	1 .2	93
23	En	4	4	1 .8	88
	Mi	11	32	1 .3	93
	Te	14	6	2 .4	87
24	Di	5	33	3 .0	87
	Mi	10	10	1 .3	93
	En	12	57	1 .8	88
	Rh	20	44	4 .4	86
25	Mi	8	47	1 .3	93
	Te	11	25	2 .5	87
	En	21	51	1 .9	88
26	Mi	7	24	1 .3	93
	Di	23	15	3 .2	87
27	Mi	6	2	1 .4	93
	En	6	44	2 .0	88
	Te	8	44	2 .6	87
28	Mi	4	39	1 .4	93
	En	15	38	2 .0	88
	Ti	23	19	10 .6	82
29	Mi	3	16	1 .4	93
	Te	6	3	2 .7	87
	Rh	9	12	4 .9	85
	Di	16	57	3 .4	87
30	En	0	31	2 .1	88
	Mi	1	54	1 .5	93
31	Mi	0	31	1 .5	93
	Te	3	22	2 .8	87
	En	9	25	2 .1	88

		Gr. M. T.		*s*	*p*
Oct. 31	Mi	23^h	8^m	1″.5	93° East
Nov. 1	Di	10	39	3.5	87
	En	18	18	2.2	88
	Mi	21	46	1.5	93
2	Te	0	41	2.8	86
	Mi	20	23	1.6	93
	Rh	21	40	5.2	85
3	En	3	12	2.2	88
	Mi	19	0	1.6	92
	Te	22	0	2.9	86
4	Di	4	22	3.7	87
	En	12	5	2.3	88
	Mi	17	38	1.6	92
5	Mi	16	15	1.6	92
	Te	19	19	3.0	86
	En	20	59	2.3	88
6	Mi	14	52	1.7	92
	Di	22	4	3.8	87
7	En	5	52	2.4	88
	Rh	10	7	5.5	85
	Mi	13	30	1.7	92
	Te	16	38	3.1	86
8	Mi	12	7	1.7	92
	En	14	46	2.4	88
9	Mi	10	44	1.7	92
	Te	13	57	3.2	86
	Di	15	46	4.0	87
	En	23	39	2.5	88
10	Mi	9	22	1.8	92
11	Mi	7	59	1.8	92
	En	8	33	2.5	88
	Te	11	16	3.2	86
	Rh	22	35	5.7	85
12	Mi	6	36	1.8	92
	Di	9	29	4.1	86
	En	17	26	2.5	88
13	Mi	5	14	1.8	92
	Te	8	35	3.3	86
	Ti	22	22	13.0	81
14	En	2	20	2.6	88
	Mi	3	51	1.8	92
15	Mi	2	28	1.9	92
	Di	3	11	4.2	86
	Te	5	54	3.3	86
	En	11	13	2.6	88
16	Mi	1	6	1.9	92
	Rh	11	3	6.0	85
	En	20	7	2.7	88
	Mi	23	43	1.9	92
17	Te	3	13	3.4	86
	Di	20	53	4.3	86
	Mi	22	20	1.9	92
18	En	5	0	2.7	87
	Mi	20	58	1.9	92
19	Te	0	32	3.4	86
	En	13	54	2.7	88
	Mi	19	35	1.9	92
20	Di	14	35	4.4	86
	Mi	18	12	1.9	92
	Te	21	51	3.4	86
	En	22	47	2.7	88
Nov. 20	Rh	23^h	31^m	6″.2	85° East
21	Mi	16	50	1.9	92
22	En	7	41	2.8	88
	Mi	15	27	2.0	92
	Te	19	10	3.4	86
23	Di	8	18	4.4	86
	Mi	14	4	2.0	92
	En	16	34	2.8	88
24	Mi	12	42	2.0	92
	Te	16	29	3.5	86
25	En	1	28	2.8	88
	Mi	11	19	2.0	92
	Rh	11	59	6.3	85
26	Di	2	0	4.5	86
	Mi	9	56	2.0	92
	En	10	21	2.8	88
	Te	13	48	3.5	86
27	Mi	8	34	2.0	92
	En	19	15	2.8	88
28	Mi	7	11	2.0	92
	Te	11	7	3.5	86
	Di	19	42	4.5	86
29	En	4	8	2.8	88
	Mi	5	48	2.0	92
	Ti D	16	56	0.9	71
	Ti R	21	22	13.8	82
30	Rh	0	27	6.4	85
	Mi	4	25	2.0	92
	Te	8	26	3.5	86
	En	13	2	2.8	88
Dec. 1	Mi	3	3	2.0	92
	Di	13	25	4.5	86
	En	21	55	2.8	88
2	Mi	1	40	2.1	92
	Te	5	46	3.6	87
3	Mi	0	17	2.1	92
	En	6	49	2.9	88
	Mi	22	55	2.1	92
4	Te	3	5	3.6	87
	Di	7	7	4.5	86
	Rh	12	54	6.5	86
	En	15	42	2.9	88
	Mi	21	32	2.1	92
5	Mi	20	9	2.1	92
6	Te	0	24	3.6	87
	En	0	36	2.9	88
	Mi	18	47	2.1	92
7	Di	0	49	4.5	87
	En	9	29	2.9	88
	Mi	17	24	2.1	92
	Te	21	43	3.6	87
8	Mi	16	1	2.1	92
	En	18	23	2.9	88
9	Rh	1	22	6.5	86
	Mi	14	38	2.1	92
	Di	18	32	4.5	87
	Te	19	2	3.6	87
10	En	3	16	2.9	88
	Mi	13	16	2.1	92
11	Mi	11	53	2.1	92
	En	12	10	2.9	88

		Gr. M. T.		s	p
ec. 11	Te	16h	21m	3″.6	87° East
12	Mi	10	30	2 .1	92
	Di	12	14	4 .5	87
	En	21	3	2 .9	88
13	Mi	9	8	2 .1	92
	Te	13	40	3 .6	88
	Rh	13	50	6 .4	87
14	En	5	57	2 .9	88
	Mi	7	45	2 .1	92
15	Di	5	56	4 .5	88
	Mi	6	22	2 .1	92
	Te	10	59	3 .6	88
	En	14	50	2 .9	88
	Ti D	16	27	1 .9	77
	Ti R	20	19	13 .0	83
16	Mi	4	59	2 .1	92
	En	23	44	2 .9	88
17	Mi	3	37	2 .1	92
	Te	8	18	3 .6	88
	Di	23	39	4 .5	88
18	Mi	2	14	2 .1	92
	Rh	2	18	6 .4	87
	En	8	37	2 .9	88
19	Mi	0	51	2 .1	92
	Te	5	37	3 .6	88
	En	17	31	2 .9	89
	Mi	23	28	2 .1	92
20	Di	17	21	4 .4	88
	Mi	22	6	2 .1	92
21	En	2	24	2 .8	89
	Te	2	56	3 .5	88
	Mi	20	43	2 .1	92
22	En	11	18	2 .8	89
	Rh	14	46	6 .3	87
	Mi	19	20	2 .0	92
23	Te	0	15	3 .5	89
	Di	11	3	4 .4	89
	Mi	17	38	2 .0	92
	En	20	11	2 .8	89
24	Mi	16	35	2 .0	92
	Te	21	34	3 .5	89
25	En	5	5	2 .8	89
	Mi	15	12	2 .0	92
26	Di	4	45	4 .3	89
	Mi	13	49	2 .0	92
	En	13	58	2 .8	89
	Te	18	53	3 .4	89
27	Rh	3	13	6 .1	88
	Mi	12	27	2 .0	92
	En	22	52	2 .7	89
28	Mi	11	4	2 .0	92
	Te	16	12	3 .4	89
	Di	22	28	4 .3	89
29	En	7	45	2 .7	89
	Mi	9	41	2 .0	92
30	Mi	8	18	2 .0	92
	Te	13	31	3 .3	89
	En	16	39	2 .7	89

		Gr. M. T.		s	p
Dec. 31	Mi	6h	56m	2″.0	92° East
	Rh	15	41	5 .9	88
	Ti D	16	3	2 .0	84
	Di	16	10	4 .2	89
	Ti R	19	9	10 .8	87
1908					
Jan. 1	En	1	32	2 .6	89
	Mi	5	33	1 .9	92
	Te	10	51	3 .3	89
2	Mi	4	10	1 .9	92
	En	10	25	2 .6	90
3	Mi	2	47	1 .9	92
	Te	8	10	3 .3	90
	Di	9	52	4 .1	90
	En	19	19	2 .6	90
4	Mi	1	25	1 .9	92
5	Mi	0	2	1 .9	92
	Rh	4	9	5 .7	89
	En	4	12	2 .5	90
	Te	5	29	3 .2	90
	Mi	22	39	1 .9	92
6	Di	3	34	4 .0	90
	En	13	6	2 .5	90
	Mi	21	16	1 .9	92
7	Te	2	48	3 .2	90
	Mi	19	43	1 .9	92
	En	21	59	2 .5	90
8	Mi	18	31	1 .9	92
	Di	21	17	3 .9	90
9	Te	0	7	3 .1	90
	En	6	53	2 .4	90
	Rh	16	37	5 .5	90
	Mi	17	8	1 .9	92
10	Mi	15	45	1 .9	92
	En	15	46	2 .4	91
	Te	21	26	3 .0	91
11	Mi	14	22	1 .9	92
	Di	14	59	3 .8	91
12	En	0	40	2 .3	91
	Mi	13	0	1 .8	92
	Te	18	45	3 .0	91
13	En	9	33	2 .3	91
	Mi	11	37	1 .8	92
14	Rh	5	5	5 .1	91
	Di	8	41	3 .6	92
	Mi	10	14	1 .8	92
	Te	16	4	2 .9	91
	En	18	27	2 .3	91
15	Mi	8	51	1 .8	92
16	En	3	20	2 .2	91
	Mi	7	28	1 .8	92
	Te	13	23	2 .8	91
	Ti D	15	51	1 .9	93
	Ti R	17	48	7 .3	92
17	Di	2	23	3 .4	92
	Mi	6	6	1 .8	92
	En	12	14	2 .2	91
18	Rh	17	33	4 .8	91

SHADOWS OF THE SATELLITES OF *TETHYS, DIONE, RHEA.*

Crossing the minor axis of the disk at the distance y from the center.

		Gr. M. T.	y	
June 21	Di	$14^{h}.7$	$0''.3$	South
	Te	20 .8	0 .8	
22	Rh	12 .4	0 .5	
23	Te	18 .1	0 .8	
24	Di	8 .4	0 .2	
25	Te	15 .4	0 .7	
27	Rh	0 .8	0 .4	
	Di	2 .1	0 .2	
	Te	12 .7	0 .7	
29	Te	10 .0	0 .7	
	Di	19 .8	0 .1	
July 1	Te	7 .3	0 .7	
	Rh	13 .3	0 .3	
2	Di	13 .5	0 .1	
3	Te	4 .6	0 .6	
5	Te	1 .9	0 .6	
	Di	7 .2	0 .0	
6	Rh	1 .7	0 .2	
	Te	23 .2	0 .6	
8	Di	0 .9	0 .0	
	Te	20 .5	0 .6	
10	Rh	14 .2	0 .2	
	Te	17 .8	0 .5	
	Di	18 .6	0 .1	North
12	Te	15 .2	0 .5	South
13	Di	12 .3	0 .1	North
14	Te	12 .5	0 .5	South
15	Rh	2 .6	0 .1	
16	Di	6 .0	0 .2	North
	Te	9 .8	0 .5	South
18	Te	7 .1	0 .4	
	Di	23 .7	0 .2	North
19	Rh	15 .0	0 .0	
20	Te	4 .4	0 .4	South
21	Di	17 .4	0 .3	North
22	Te	1 .7	0 .4	South
23	Te	23 .0	0 .4	
24	Rh	3 .5	0 .1	North
	Di	11 .0	0 .3	
25	Te	20 .3	0 .3	South
27	Di	4 .7	0 .4	North
	Te	17 .6	0 .3	South
28	Rh	15 .9	0 .1	North
29	Te	14 .9	0 .3	South
	Di	22 .4	0 .4	North
31	Te	12 .2	0 .3	South
Aug. 1	Di	16 .1	0 .5	North
2	Rh	4 .4	0 .2	
	Te	9 .6	0 .2	South
4	Te	6 .9	0 .2	
	Di	9 .8	0 .5	North
6	Te	4 .2	0 .2	South
	Rh	16 .8	0 .3	North
7	Di	3 .5	0 .5	
8	Te	1 .5	0 .2	South
9	Di	21 .2	0 .6	North
	Te	22 .8	0 .1	South
11	*Rh*	5 .3	0 .4	North
Aug. 11	Te	$20^{h}.1$	$0''.1$	South
12	Di	14 .9	0 .6	North
13	Te	17 .4	0 .1	South
15	Di	8 .6	0 .6	North
	Te	14 .7	0 .1	South
	Rh	17 .7	0 .4	North
17	Te	12 .0	0 .0	
18	Di	2 .3	0 .7	
19	Te	9 .3	0 .0	
20	Rh	6 .2	0 .5	
	Di	20 .0	0 .7	
21	Te	6 .6	0 .0	
23	Te	3 .9	0 .0	
	Di	13 .6	0 .7	
24	Rh	18 .6	0 .6	
25	Te	1 .2	0 .1	
26	Di	7 .3	0 .8	
	Te	22 .6	0 .1	
28	Te	19 .9	0 .1	
29	Di	1 .0	0 .8	
	Rh	7 .0	0 .6	
30	Te	17 .2	0 .1	
31	Di	18 .7	0 .9	
Sept. 1	Te	14 .5	0 .2	
2	Rh	19 .5	0 .7	
3	Te	11 .8	0 .2	
	Di	12 .4	0 .9	
5	Te	9 .1	0 .2	
6	Di	6 .1	0 .9	
7	Te	6 .4	0 .2	
	Rh	7 .9	0 .8	
8	Di	23 .8	1 .0	
9	Te	3 .7	0 .3	
11	Te	1 .0	0 .3	
	Di	17 .5	1 .0	
	Rh	20 .4	0 .8	
12	Te	22 .3	0 .3	
14	Di	11 .2	1 .1	
	Te	19 .6	0 .3	
16	Rh	8 .8	0 .9	
	Te	17 .0	0 .4	
17	Di	4 .9	1 .1	
18	Te	14 .3	0 .4	
19	Di	22 .6	1 .1	
20	Te	11 .6	0 .4	
	Rh	21 .2	0 .9	
22	Te	8 .9	0 .4	
	Di	16 .2	1 .2	
24	Te	6 .2	0 .5	
25	Rh	9 .7	1 .0	
	Di	9 .9	1 .2	
26	Te	3 .5	0 .5	
28	Te	0 .8	0 .5	
	Di	3 .6	1 .2	
29	Te	22 .1	0 .5	
	Rh	22 .2	1 .1	
30	Di	21 .3	1 .3	

			Gr. M. T.	y	
Oct.	1	Te	19h.4	0″.5	North
	3	Di	15 .0	1 .3	
		Te	16 .8	0 .6	
	4	Rh	10 .6	1 .1	
	5	Te	14 .1	0 .6	
	6	Di	8 .7	1 .3	
	7	Te	11 .4	0 .6	
	8	Rh	23 .0	1 .2	
	9	Di	2 .4	1 .3	
		Te	8 .7	0 .6	
	11	Te	6 .0	0 .6	
		Di	20 .1	1 .4	
	13	Te	3 .3	0 .7	
		Rh	11 .5	1 .3	
	14	Di	13 .8	1 .4	
	15	Te	0 .6	0 .7	
	16	Te	21 .9	0 .7	
	17	Di	7 .5	1 .4	
	18	Rh	0 .0	1 .3	
		Te	19 .2	0 .7	
	20	Di	1 .2	1 .4	
		Te	16 .6	0 .7	
	22	Rh	12 .4	1 .4	
		Te	13 .9	0 .8	
		Di	18 .9	1 .5	
	24	Te	11 .2	0 .8	
	25	Di	12 .6	1 .5	
	26	Te	8 .5	0 .8	
	27	Rh	0 .9	1 .5	
	28	Te	5 .8	0 .8	
		Di	6 .3	1 .5	
	30	Te	3 .1	0 .9	
	31	Di	0 .0	1 .6	
		Rh	13 .3	1 .5	
Nov.	1	Te	0 .5	0 .9	
	2	Di	17 .7	1 .6	
		Te	21 .8	0 .9	
	4	Te	19 .1	0 .9	
	5	Rh	1 .8	1 .6	
		Di	11 .4	1 .6	
	6	Te	16 .4	1 .0	
	8	Di	5 .1	1 .7	
		Te	13 .7	1 .0	
	9	Rh	14 .3	1 .7	
	10	Te	11 .0	1 .0	
		Di	22 .8	1 .7	
	12	Te	8 .3	1 .0	
	13	Di	16 .5	1 .7	
	14	Rh	2 .7	1 .8	
		Te	5 .6	1 .1	
	16	Te	3 .0	1 .1	
		Di	10 .2	1 .8	
	18	Te	0 .3	1 .1	
		Rh	15 .2	1 .8	
	19	Di	3 .9	1 .8	
		Te	21 .6	1 .2	
	21	Te	18 .9	1 .2	
		Di	21 .6	1 .8	
	23	Rh	3 .6	1 .9	
		Te	16 .2	1 .2	
	24	*Di*	*15 .3*	*1 .9*	

			Gr. M. T.	y	
Nov.	25	Te	13h.6	1″.3	North
	27	Di	9 .0	1 .9	
		Te	10 .9	1 .3	
		Rh	16 .1	2 .0	
	29	Te	8 .2	1 .3	
	30	Di	2 .8	2 .0	
Dec.	1	Te	5 .5	1 .4	
	2	Rh	4 .6	2 .1	
		Di	20 .4	2 .0	
	3	Te	2 .8	1 .4	
	5	Te	0 .1	1 .4	
		Di	14 .2	2 .1	
	6	Rh	17 .0	2 .1	
		Te	21 .5	1 .5	
	8	Di	7 .9	2 .1	
		Te	19 .8	1 .5	
	10	Te	16 .1	1 .5	
	11	Di	1 .6	2 .1	
		Rh	5 .5	2 .2	
	12	Te	13 .4	1 .5	
	13	Di	19 .3	2 .2	
	14	Te	10 .7	1 .6	
	15	Rh	18 .0	2 .3	
	16	Te	8 .0	1 .6	
		Di	13 .0	2 .2	
	18	Te	5 .4	1 .6	
	19	Di	6 .7	2 .3	
	20	Te	2 .7	1 .6	
		Rh	6 .5	2 .4	
	22	Te	0 .0	1 .7	
		Di	0 .4	2 .3	
	23	Te	21 .3	1 .7	
	24	Di	18 .1	2 .3	
		Rh	18 .9	2 .5	
	25	Te	18 .6	1 .7	
	27	Di	11 .8	2 .4	
		Te	16 .0	1 .8	
	29	Rh	7 .4	2 .5	
		Te	13 .3	1 .8	
	30	Di	5 .5	2 .4	
	31	Te	10 .6	1 .8	
1908.					
Jan.	1	Di	23 .2	2 .5	
	2	Te	7 .9	1 .9	
		Rh	19 .9	2 .6	
	4	Te	5 .2	1 .9	
		Di	17 .0	2 .5	
	6	Te	2 .6	1 .9	
	7	Rh	8 .3	2 .7	
		Di	10 .7	2 .6	
		Te	23 .9	2 .0	
	9	Te	21 .2	2 .0	
	10	Di	4 .4	2 .6	
	11	Te	18 .5	2 .0	
		Rh	20 .8	2 .7	
	12	Di	22 .1	2 .7	
	13	Te	15 .8	2 .1	
	15	Te	13 .2	2 .1	
		Di	15 .8	2 .7	
	16	Rh	9 .3	2 .8	
	17	Te	10 .5	2 .1	

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter...	July 2,	6^h	34^m	A.M.	New Moon....	Aug. 8,	10^h 36^m P.M.
New Moon	" 10,	7	17	A.M.	First Quarter..	" 16,	1 5 P.M.
First Quarter...	" 18,	5	12	A.M.	Full Moon.....	" 23,	4 15 A.M.
Full Moon	" 24,	8	30	P.M.	Last Quarter..	" 30,	9 28 A.M.
Last Quarter...	" 31,	6	25	P.M.			

The Earth reaches aphelion—that is, reaches its greatest distance from the Sun—July 5th, 7 A.M. Pacific time.

There will be two eclipses during July. The first is *an annular eclipse of the Sun* on July 10th, not visible in the United States. The path of central eclipse begins in the South Pacific, crosses South America, and ends in the South Atlantic.

The second is *a partial eclipse of the Moon* on the evening of July 24th. The beginning of the actual eclipse is visible generally throughout North America except the northwest portion, and the end throughout North America except Alaska. The principal phases are as follows, Pacific time:—

Moon enters penumbra, July 24,	5^h	59^m	P.M.
Moon enters shadow..	7	4	P.M.
Middle of the eclipse..	8	22	P.M.
Moon leaves shadow...	9	41	P.M.
Moon leaves penumbra	10	46	P.M.

The maximum obscuration of the Moon is a little more than six tenths of the Moon's diameter.

Mercury on July 1st is an evening star, having passed greatest east elongation on June 27th, and sets about an hour and one half after sunset. It is therefore at this time in fine position for observation, but it soon draws too near the Sun to be seen, and passes inferior conjunction on the evening of July 24th, becoming a morning star. It then moves rapidly away from the Sun, reaching greatest west elongation (18° 51′) on August 12th. It then rises about an hour and one half before sunrise and will be an easy object in the morning twilight. By the end of the month it has nearly *reached superior* conjunction with the Sun.

Venus is still a morning star, rising 1^h 24^m before sunrise July 1st, 1^h 3^m August 1st, and less than half an hour before on August 30th. It cannot easily be seen by the naked eye much after the first week in August. By the end of that month it will nearly have reached superior conjunction with the Sun.

During the latter part of July and through August *Mercury, Venus, Jupiter,* and *Neptune* are all very close together in the early morning sky just above the eastern horizon, and a good many conjunctions occur. *Mercury* is in conjunction with *Jupiter* July 31st, 8 P.M., and with *Venus* at 5 A.M. on August 1st,—not very close approaches, *Mercury* being nearly 5° south in each case. Next, on August 1st, 9 A.M., *Venus* and *Jupiter* are in conjunction, *Venus* being only 18′ north of *Jupiter*. *Mercury* and *Jupiter* are again in conjunction on August 10th, *Mercury* 2° 5′ south.

Mars comes to opposition with the Sun July 6th, 7 A.M. Pacific time, and is then above the horizon during the entire night. On August 1st it is above the horizon until about 2 A.M., and on August 31st it sets about half an hour after midnight. During most of the period it is moving westward, having begun this motion on June 5th. From July 1st to August 13th it moves about 8°, going back along a line somewhat south of its eastward motion in the spring, and at the latter date it occupies a position among the stars 5° south of its position on April 18th. From August 13th it moves eastward again, making about 4° before the end of the month, on a line a little north of the preceding westward motion. It does not reach its minimum distance from the Earth until July 13th, a week after opposition, and throughout July its distance varies only a little more than two millions of miles. During August the distance increases by about ten millions, and by the end of the month the brightness will diminish perceptibly, but will still exceed that of any of the fixed stars.

Jupiter is still an evening star on July 1st, but sets less than an hour after sunset, and it will not be an easy object for naked-eye observation. It comes to conjunction with the Sun July 15th, 11 P.M., and becomes a morning star. On August 1st it rises about an hour before sunrise, and on August 31st nearly three hours before.

Saturn rises at about 11^h 30^m P.M. on July 1st, at about 9^h 30^m *P.M. on August 1st,* and before 7^h 30^m P.M. on August

31st. It moves about 7° westward and 1° southward in the constellation *Pisces*. On July 1st the Earth is below and the Sun above the plane of the rings, so that we still have the dark face of the rings toward us. About July 25th the plane of the rings crosses the Sun, and from then until October Sun and Earth are on the same side of the plane. The rings are seen nearly edgewise, the minor axis being in the maximum at the end of July not more than four per cent of the major in the apparent ellipse, and this will diminish as the Earth approaches the plane of the rings.

Uranus is in opposition to the Sun on July 3d, and is then above the horizon during the entire night. On August 1st it sets at about 2^h 40^m A.M., and at about 12^h 40^m A.M. on August 31st. During the two months it moves about 2° westward in the constellation *Sagittarius* north of the "milk-dipper." *Uranus* is not far from *Mars* throughout the two months, and is in conjunction with it twice,—on July 19th, when *Mars* passes 5° 18′ south of it, and again on August 24th, when *Mars* passes 4° 37′ south, the motion of *Mars* being westward on the first occasion and eastward on the second.

Neptune is in conjunction with the Sun on the morning of July 5th, and becomes a morning star.

REVIEW.[1]

Resultate des Internationalen Breitendienstes. Vol. I (1903), by Th. Albrecht. Vol. II (1906), by Th. Albrecht and B. Wanach. Centralbureau der Internationalen Erdmessung; neue Folge der Veröffentlichungen, Nos. 8 und 13.

In the latter part of 1899 six astronomical stations were established in the northern hemisphere for the purpose of making systematic observations for the latitude of each station in order to determine the variations in this quantity. Observations at the six stations have been carried on continuously since they were established without serious interruption from any cause, and are to be continued into the future for an indefinite period of time. This work is being prosecuted by the International Geodetic Association, which has headquarters at Potsdam, Germany. This association was formed for the purpose of conducting geodetic undertakings which are international in character. It is supported by the most prominent nations of the world, including nearly all the governments of Europe, the United States, the Argentine Republic, and Japan. The geodetic institutes of the various countries in which the latitude stations are located co-operate with the central station in carrying on this particular piece of work, the three stations in the United States being under the supervision of the Coast and Geodetic Survey.

Thus far the International Geodetic Association has pubished two volumes (under the title at the head of this review) giving the results of the observations for the variation of latitude. Volume I contains all of the observations made

[1] The writer of this review has endeavored to make it both popular and technical. It is hoped that the general reader may be able to get from it a general knowledge of the problems presented under the head of the variation of latitude and the methods by which they are attacked. It is hoped also that the professional astronomer or the student of astronomy who cares to look into the subject more carefully may be able to get from it a fair idea of the details of the processes involved. No attempt has been made by the reviewer to explain in detail the parts which are purely technical and not essential to a general understanding of the problems involved. In a number of places the language of the authors has been followed quite closely, but in no case is the translation literal enough to warrant the use of quotation-marks. For some of the opinions expressed, and for Figure 1, and for the computations under the theory of probabilities, the authors are in no wise responsible. In order to protect them, some of the statements, with which the reader might not agree, and for which the reveiwer alone is responsible, are followed by the letter *r* in parenthesis.

from the time the stations were established until January 4, 1902, and Volume II the observations obtained in the interval from January 5, 1902, to January 4, 1905. A third volume is in the course of preparation.

The contents of Volume I are presented under eight headings, which are indicated by italics in the following paragraphs.

Introduction.—The phenomenon of the variation of latitude was first detected in 1889 by Dr. KÜSTNER, astronomer in the Royal Observatory at Berlin. Various observations and investigations during the first half of the last decade of the nineteenth century established the reality and the nature of the phenomenon, and steps toward a systematic and thorough attack upon the problems presented were first taken by the International Geodetic Association in 1895.

In selecting the stations, social, hygienic, seismological, and meteorological, as well as mathematical, conditions were considered, the prime requisite being, of course, that all of the stations should have a fair proportion of clear nights at all seasons of the year. Seventeen different combinations of stations lying between latitudes $+36° 48'$ and $+44° 50'$, and including two combinations in the southern hemisphere on parallels $-33° 54'$ and $-33° 27'$, were considered. The parallel of $+39° 8'$ was finally chosen with the stations located in Japan, in Italy, and in the eastern and western parts of North America. Two other stations were subsequently added, one in Central Asia and the other in the central part of North America, at Cincinnati.

For the four stations first established—Mizusawa, Carloforte, Gaithersburg, and Ukiah—four new instruments exactly alike were constructed by WANSCHAFF in Berlin, 108^{mm} aperture, 130^{cm} focal length, 104 magnification. The instruments at Tschardjui and Cincinnati, by the same maker, are smaller, 68^{mm} aperture, 87^{cm} focus, and 81^{mm} aperture, 100^{cm} focus, respectively, both having 100 magnifying power.

The Horrebow-Talcott method[1] of observation was selected as the best suited for the purpose of determining the latitude.

[1] Descriptions of this method may be found in any work on practical or general astronomy. The following statements concerning the method may be of help to those who are not familiar with its details. In order to make a determination of the latitude by this method it is necessary to measure, by means of an eye-piece micrometer attached to the zenith-telescope, the *difference* of zenith-distance of two stars of known declination which culminate at nearly equal zenith-distances, one north of and the other south of the zenith. The telescope is set at the mean

Twelve groups of stars, each containing six pairs at small zenith distances (not more than 24°) and two pairs at large zenith-distance (about 60°), were selected. The stars were chosen by Dr. KIMURA, astronomer in charge of the Japanese station at Mizusawa. The magnitudes of the stars lie between 4.0 and 7.4, and the intervals between their culminations vary between four and sixteen minutes.

Two groups extending over four hours are observed each night according to the following programme:—

Group.	R. A.	To be Observed From	To	Duration of Group.	Group Connection.
I	0^h – 2^h	Sept 23	Dec. 6	74 days	35 days
II	2 – 4	Nov. 2	Jan. 4	64	29
III	4 – 6	Dec. 7	Jan 30	55	26
IV	6 – 8	Jan. 5	Feb. 24	51	25
V	8 – 10	Jan. 31	Mar. 21	50	25
VI	10 – 12	Feb. 25	Apr. 15	50	25
VII	12 – 14	Mar. 22	May 11	51	26
VIII	14 – 16	Apr. 16	June 8	54	28
IX	16 – 18	May 12	July 9	59	31
X	18 – 20	June 9	Aug. 13	66	35
XI	20 – 22	July 10	Sept. 22	75	40
XII	22 – 24	Aug 14	Nov. 1	80	40

of the zenith distances of the two stars and the first to culminate will pass a little above or below the middle of the field of view. This distance from the middle of the field is measured by means of the micrometer. The instrument is then reversed about its vertical axis without disturbing the setting, and the telescope will then point as far south as it did north of the zenith before reversal, or *vice versa*. The second star will then pass through the field of view as far below or above as the first star was above or below the center, and this distance from the center is again measured by means of the micrometer. The proper combination of the micrometer settings on the two stars gives the actual difference of their zenith distances, which may be turned into arc measure, provided the value of one revolution of the micrometer screw be known. The latitude, ϕ, of the place of observation is computed by means of the formula,

$$\phi = \tfrac{1}{2}(\delta_n + \delta_s) + \tfrac{1}{2}(m_n - m_s)R + \tfrac{1}{2}(l_n + l_s) + \tfrac{1}{2}(r_n - r_s),$$

in which the first term of the right hand member of the equation represents one half the sum of the declinations of the two stars of the pair observed, the second term one half the difference of the zenith distances of the two stars as measured by means of the micrometer, the third term a small correction for any change in the pointing of the telescope after reversal, detected by means of two very delicate levels attached to the telescope, and the last term a small correction for the *difference* in the atmospheric refraction affecting the rays of light coming from the two stars. It might be noticed that if the two stars are at *exactly* the same zenith distance, and the instrument is reversed without disturbing the pointing, then the second, third, and fourth terms each become zero in the equation above, and the latitude is nothing other than the mean of the declinations of the two stars, or the declination of the zenith.

As two groups are observed each night, it is seen that each group will be observed both with the preceding and the following one, for lengths of time which vary between twenty-five and forty days. This interval is made to vary simply for the convenience of the observer, for by this means the observing time is made to come earlier in the evening during the winter months than during the summer months. In winter the observations lie between 7 P.M. and 1 A.M., in summer between 9 P.M. and 3 A.M. The time of beginning is never less than one and one-half hours after sunset, and the time of ending never less than one and three-quarter hours before sunrise. As the heating effects before sunrise are less pronounced than the cooling effects after sunset, it might perhaps have been wise to shift the whole programme a little further into the night. (*r*)

The observatory buildings at the six stations are of similar construction but differ somewhat in details. The one at Ukiah is three meters square, built of wood, with tin roof, and surrounded by an open slatwork construction which serves in some measure to protect the building within from the fierce rays of the summer sun. The roof is divided in the meridian-line and mounted upon rollers so that the two halves may be rolled apart, one to the east, the other to the west, giving a maximum opening of 1.8 meters. A small house to protect the meridian targets is located fifty-five meters north of the telescope.

Description of the Stations.—Detailed descriptions of the six stations and their surroundings are given, covering eight pages of the quarto volume. A few of the chief facts only will be mentioned here.

The city of Mizusawa (10,000 inhabitants) is situated on the principal Japanese island (Nippon), 466 kilometers north of Tokyo. The city lies in a north and south valley 180 kilometers long and five to fifteen kilometers wide. There are ranges of mountains to the east and to the west of the valley, the highest peak having an altitude of 2,200 meters. The valley is given largely to the cultivation of rice. The observatory is located about one kilometer south of the city. The number of earthquakes at Mizusawa is large, but the locality is not affected by these disturbances as much as some other portions of Japan. The zenith-telescope at this station was injured during the transport from Potsdam and the observations obtained with it

during the first year were subject to rather large errors. There are two observers at Mizusawa, Dr. H. KIMURA and Dr. T. NAKANO, who have served continuously since the observatory was established.

Tschardjui is located east of the southern end of the Caspian Sea in the Central Asian possessions of the Russian Government. The station lies nine and one-half kilometers northwest of the city and three kilometers from the left bank of the Amu Daria or river Oxus. The observatory is located on an oasis in a sand-waste traversed by many canals. There is a greater range in the annual temperature at this station than at any of the others. The early observations at Tschardjui did not show a satisfactory agreement among themselves. This was found to be due to a poor level and the use of oil illumination. Electric illumination was substituted and the level discarded. It might not be out of place to remark, parenthetically, that it is now generally admitted that the heat from oil-lamps may have a very injurious effect upon observations in which a high degree of precision is expected. Since a satisfactory electric illumination for intermittent work may be obtained by the use of any good make of ordinary dry cells, there seems to be no longer any excuse for using oil illumination for work with a zenith-telescope or altazimuth. (*r*)

Tschardjui is affected by very few earthquakes. The observations at this station are made by a single observer. Several have thus far taken part, and they have all been officers of the Russian army.

The Italian station has a very picturesque location on an old tower, San Vittorio, on the island of San Pietro, one kilometer southwest of the city of Carloforte. The tower is located on a peninsula on the east side of the island, so that the meridian of the observatory lies entirely over the Mediterranean Sea, with the exception of 260 meters to the north and 220 meters to the south, and anomalies in the refraction would seem to be absolutely excluded. The island is free from mountains, the highest point being 211 meters above sea-level. The altitude of the observatory is twenty-two meters. Carloforte has 8,000 inhabitants and can be reached from Cagliari, the chief city of Sardinia, in eight hours. The island is free from earthquakes, there having been only four in nearly four hundred years of any considerable intensity, and none of these destruc-

tive. The observations at this station are made by two observers, who alternate with the nights. Several changes in the staff have taken place thus far, but all its members have been Italian astronomers.

The Gaithersburg Observatory is located one kilometer south of the village of that name, which is thirty-three kilometers northwest of the city of Washington. The observatory has an altitude of 165 meters above sea-level; the surrounding country is hilly. Mr EDWIN SMITH, of the Coast and Geodetic Survey, made the observations at this station during the first year; Dr. HERMAN S. DAVIS during the succeeding five years. The work is now in charge of Dr. FRANK E. ROSS.

After the parallel of 39° 8′ had been selected for the location of the latitude stations it was found that this parallel passed through the grounds of the observatory of the University of Cincinnati, and Professor J. G. PORTER, director of the observatory, volunteered to carry on observations if he were provided with an instrument. The observatory is located upon a hill, twenty meters higher than the surrounding country, eight kilometers northeast of the city, and two kilometers east of the Ohio River. The altitude of the observatory is 247 meters above sea-level. Thus far all of the observations, except a few during the summer months, have been made by Professor PORTER.

The California station is situated two kilometers south of the city of Ukiah, the county seat of Mendocino County. The observatory is located toward the western edge of one of the numerous small valleys in the Coast Range of mountains. The valley, which is traversed by the Russian River, is about fifteen kilometers long and from three to five kilometers wide, and surrounded by mountains of an average height of about 400 meters above the floor of the valley. The altitude of the observatory is 220 meters above sea-level Up to May, 1903, the observations at this station were made by Dr. FRANK SCHLESINGER, now director of the Allegheny Observatory; since that time the work has been in charge of the writer of this review.

From a seismological point of view all of the American stations are favorably located Although the Pacific Coast is well recognized as a region of seismic activity, yet the mountainous character of the country surrounding Ukiah seems to

afford a measure of protection from these disturbances. No earthquake since the observatory was established, not even the great shock of April 18, 1906, has been of sufficient intensity to in any way interfere with the progress of observations.

Instrumental Constants.—The most important constants to be determined in the case of a zenith-telescope are the angular value of one revolution of the micrometer-screw and the angular value of one space of the levels.

The pairs of stars have been so chosen that an error in the value of a revolution of the micrometer-screw will be eliminated from the mean of the latitude derived from each group. If the mean of the declinations of the stars of a pair, $\frac{1}{2}(\delta_n + \delta_s)$, is less than the latitude it must be increased by half the difference of the zenith-distances as measured by means of the micrometer. If $\frac{1}{2}(\delta_n + \delta_s)$ is greater than the latitude, then the micrometer correction is to be applied with a negative sign. If now the value of a revolution of the micrometer-screw used is too small, all of the micrometer corrections will be *numerically* too small, and hence latitudes in the first case above will all be too small, and in the second case all too large. Hence, if in any group the sum of the positive micrometer corrections is made equal to the sum of the negative corrections, the errors will be eliminated in the mean latitude as determined from that group. On account of the precession this elimination will hold only for a certain epoch, and the same group cannot therefore be used for an indefinite period. In the work of the International Geodetic Association the first selection of groups was used for six years, three years on either side of the epoch 1903.0.

The angular value of one revolution of the micrometer-screws was determined by the use of two methods, transits of polar stars at elongation, and measurement of differences of declination of stars as they come to the meridian. The second of these methods was used only at Cincinnati and Ukiah. The chief objection to it is that the results are affected by whatever errors may pertain to the declinations of the stars used. The first method, transits of polar stars at elongation, is theoretically preferable, but in practice gives results which show rather a large and unsatisfactory range. This is very likely due to the fact that the observer must assume either that the angle between the line of sight of the telescope and the vertical

remains unchanged during the progress of the observations, an hour, more or less, or that any changes in this angle are truthfully indicated by the readings of the latitude levels. Levels at their best are untrustworthy instruments, and in this case, since it is necessary for the observer to stand during the whole progress of the observations near the south end of the level tubes, it is easily conceivable that the heat from the observer's body may so affect the levels that a change in the reading of the bubbles may take place without any corresponding change in the pointing of the telescope, or *vice versa*. (*r*)

The value of one revolution of the micrometer-screw depends of course upon the temperature at which the determination is made. The range in temperatures at Carloforte and Ukiah is not sufficient to enable a good determination of the temperature coefficient to be made, and the observed values at the other stations depart rather widely from the theoretical values computed from the coefficients of expansion of brass and steel and the known values of one revolution of the screws. These differences are to be explained through the statement that the temperature coefficient evidently depends upon factors other than those just stated.

All of the screws were investigated for both progressive and periodic errors, either by observation of polar stars at elongation or by the use of auxiliary apparatus. Periodic errors of a sensible magnitude were found only for the instruments at Tschardjui and Carloforte. The screw of the Cincinnati telescope was found to be practically free from both progressive and periodic errors. The progressive errors of the screws at Carloforte and Gaithersburg were found to be considerably larger than the values obtained at Potsdam in tests applied before the instruments were shipped. The only explanation seems to be that the screws were damaged in some way during transportation.

The values of the spaces of the latitude levels were determined by micrometric settings upon the mire or by the use of a level-trier. At Ukiah a new method of observing stars of nearly the same declination was tried by Dr. SCHLESINGER with good success. This method has certain decided advantages and the details of it have already been explained in these *Publications* (Vol. XIII, p. 13). The effect of temperature and barometric pressure on the levels was not investigated.

Instrumental Errors.—Before making observations for latitude with a zenith-telescope it is necessary to so adjust the instrument that any instrumental errors which may remain shall be so small that they will not have an appreciable effect upon the accuracy of the results to be obtained. In order to attain this end the vertical axis must be made truly vertical, or very nearly so, the horizontal axis truly horizontal and in the plane of the prime vertical and the collimation zero, or rather of the same magnitude as the flexure of the horizontal axis, in order that the one may counteract the other, or that the collimation minus the flexure may be nearly zero. The position of the axes may be tested by means of the levels attached to the instrument and by the mire. The collimation, flexure, and position of the meridian targets can be tested only by observations of the stars for time. Since the telescope in this type of instrument is attached to one end of the horizontal axis and a counterpoise of equal weight at the other end, the flexure of the horizontal axis is large, about two seconds of time, and a time determination with this instrument involves a laborious process unless the flexure be assumed as a known quantity.

Volumes I and II give the daily values of the instrumental errors for each station.

Atmospheric Conditions.—Observations of the inside and the outside temperature and of the barometric pressure are made hourly during the progress of observations. The only use to be made of these would be in the investigation of possible cases of abnormal refraction. It is the *difference* of the refraction of the two stars of a pair which enters into the computation of the latitude, and under normal conditions this may be computed for stars at small zenith-distances by means of a formula based upon a mean value of the temperature and the barometric pressure.

In addition to the individual temperature and barometric readings there is given a tabulation showing the mean temperature for each group connection at each station. The greatest range, 35°.6 centigrade, is at Tschardjui, the least at Carloforte and Ukiah, 13°.7 and 14°.8 respectively. The range in group-connection means is, from —8° to + 21° at Mizusawa, from —9° to + 26° at Tschardjui, from + 10° to + 23° at Carloforte, from — 5° to + 23° at Gaithersburg, from —4° to + 24° at Cincinnati, from + 4° to + 19° at

Ukiah. At the last-named place, although the midday temperature often reaches 40° (104° Fahrenheit), and at times has reached as high as 45° (113° Fahrenheit), yet the temperature decreases rapidly immediately after sundown, and such a thing as a hot night is practically unknown.

Results of Observations.—The individual values of the latitude from each pair observed, computed by means of the equation already given, are found in tabular form in this section. The total number of determinations made during the period covered by the first volume is 27,387. The percentage of nights upon which observations were obtained at the various stations is as follows:—

Mizusawa	48 per cent.
Tschardjui	33 "
Carloforte	70 "
Gaithersburg	48 "
Cincinnati	34 "
Ukiah	47 "
Average	47 per cent.

The conditions at Carloforte, in the Mediterranean Sea, must be almost ideal from an astronomical standpoint, still the above tabulation cannot be taken as a true index of the weather at the stations. At Carloforte and at Mizusawa two observers are constantly employed, and probably nearly every favorable night is utilized. At the other stations, where all of the observations are made by a single observer, many favorable nights must of necessity be allowed to pass. At Ukiah, for instance, the percentage could be increased by at least ten, perhaps fifteen, if two observers were employed. In considering the above table the further fact should be taken into consideration that Professor PORTER, who makes the observations at Cincinnati, has many other duties in connection with his position as director of the Cincinnati Observatory and professor of astronomy in the University of Cincinnati. With him observing for latitude is an avocation and not a vocation. We should also consider the still further fact that at some stations,—for instance, Mizusawa,—many nights are rendered incomplete by fog or clouds, and a night upon which only one pair is obtained enters into the above tabulation with the same weight as a complete night of sixteen pairs. During the 750 days since observations

were begun at the last station to start, Mizusawa, there were only five upon which observations were obtained at all six stations.

Determination of the Definitive Latitudes.—The first investigation undertaken under this heading was to determine whether or not there was a systematic difference between observations taken east-west and those taken west-east. None of significance was found except at Mizusawa, in November and December, 1900. Only the seventy-two latitude pairs were used in the definitive determination of the latitude.

The next step was to determine corrections to the declinations of the stars from the observations themselves. There are two steps in this process,—first, to determine the reductions to be applied to the results of each pair in order to reduce them to a mean declination system of the group; second, the determination of the reductions necessary to bring the groups to a common basis. The first step was accomplished by taking the mean of the results from the six zenith pairs on each night that the complete group was observed, and then subtracting the individual results, including those for the two refraction pairs, from this mean. The results for each pair at each station were then collected and the grand means taken as the corrections to $\frac{1}{2}(\delta_n + \delta_s)$ for each pair.

The total mean error of the results will be made up of the accidental errors of observation and the systematic station errors, which last are either instrumental or personal, or perhaps of an external nature, such as anomalous refraction. The numerical value of the first of these, the accidental error of observation, may, on account of the richness of the observational material, be computed from the individual observations of a pair, thus eliminating all consideration of the errors of declination. The mean error for a single observation of a pair is about $\pm 0''.15$. The total mean error of the station mean for a single pair is $\pm 0''.067$ for the latitude pairs, and $\pm 0.''090$ for the refraction pairs. These values are greater than those to be obtained from the accidental errors alone, showing that there are in fact systematic station errors. It is not possible as yet to state what these are due to, but an examination of the ten pairs having the largest differences of zenith-distance seems to show that they may lie in errors in the assumed values of the micrometer-screws.

The corrections to the group means were applied to the mean group latitudes and the results assembled on pages 121-125. From these, differences between the group results for each group connection were obtained for each station and the results collected. After the weighted means for the six stations had been taken, it was found that their algebraic sum differed appreciably from zero. One explanation of this, and perhaps the most probable, is that the value of the constant of aberration used in the star-place reductions was in error. It was found that a correction to the aberration of $+0''.042$ would cause the "Schlussfehler"—closing error—to disappear. This would change the adopted constant of aberration from $20''.470$ to $20''.512$, a change which is confirmed by other investigations entirely separate from this. It might be stated here that the computations given in volume II cast some doubt upon the reality of this correction.

From the group differences the corrections to each group were formed which are necessary to reduce the twelve groups to a common declination system based on the declinations of the seventy-two latitude pairs. From these reductions to a mean system and the reductions to the group means the final corrections to the declinations of each pair were formed and collected into a table (page 129). These corrections were then applied to the daily means at each station, and these then formed into the group combination means, the latitude pairs and the refraction pairs being treated separately.

Determination of the Path of the Pole.—The path of the pole was determined from the normal values of the latitude for each group connection. The first step in this process was to determine the mean value of the latitude for each station, and this was done by a method of successive approximations. The differences between the mean values and the individual mean group connection values were then formed and plotted with time as the x co-ordinate. A mean curve was drawn for each station and then the values of $\phi - \phi_0$ (ϕ_0 being the mean latitude of the station) were read from it for each tenth of a year, thus eliminating in a large measure the errors of observation.

It was first assumed that the motion of the pole could be represented by an equation of the form,

$$\Delta\phi = x \cos\lambda + y \sin\lambda,$$

in which $\Delta \phi = \phi - \phi_0$, λ the longitude of the place of observation west of Greenwich, x and y the rectangular co-ordinates of the instantaneous pole in a system the origin of which is located at the position of the mean pole, the x axis of which points toward Greenwich, and the y axis toward a point in 90° west longitude. The above equation may be derived easily from the following figure.

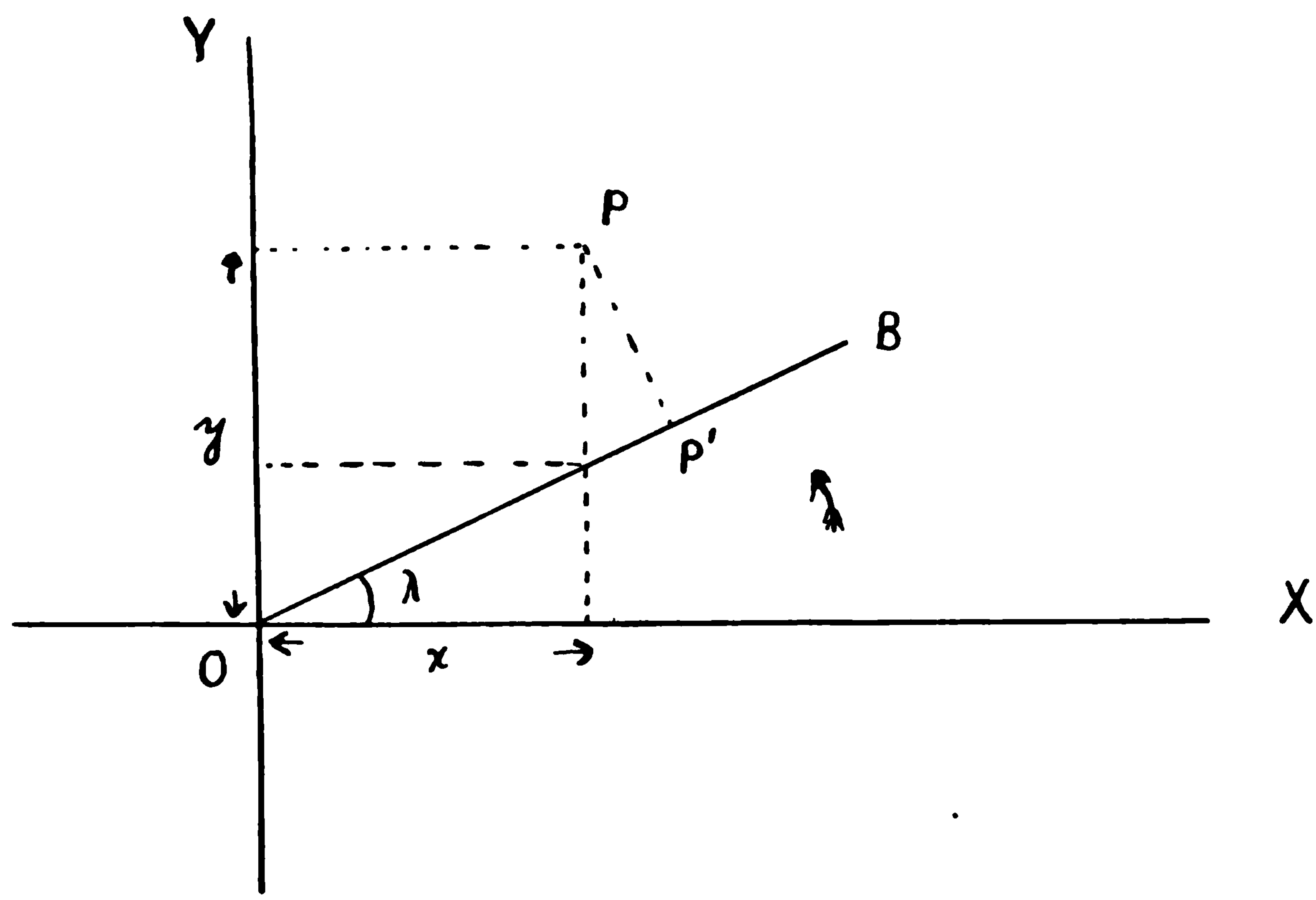


FIG. I.

Let $O B$ be the direction toward any observatory in west longitude λ, P the instantaneous position of the pole, and P' the foot of the perpendicular dropped from P upon $O B$. Then we have,

$$O P' = \Delta \phi = x \sec \lambda + (y - x \tan \lambda) \sin \lambda,$$
$$= x \left(\sec \lambda - \frac{\sin^2 \lambda}{\cos \lambda} \right) + y \sin \lambda,$$
$$= x \cos \lambda + y \sin \lambda.$$

Early investigations showed that the observations were not satisfied very well by this equation, and Dr. KIMURA suggested the introduction of a third unknown independent of the longitude, thus,

$$\Delta \phi = x \cos \lambda + y \sin \lambda + z.$$

Least-square solutions under both assumptions were made, the one involving the solution of six equations for two unknowns

at each tenth of a year, the other the solution of six equations for three unknowns at each tenth of a year. The sum of the weighted squares of the residuals is so measurably better under the second assumption that there seems to be no doubt about the existence of the term z. The largest residuals were found in the case of Gaithersburg, and they were so much larger than the others that the case seemed to demand special investigation. The period under discussion involved a change of observers at Gaithersburg, SMITH leaving at the close of 1900. The two observers, however, did not observe together long enough to determine their personal equation. It was found that the large residuals at Gaithersburg could be greatly reduced by *assuming* a personal equation of a tenth of a second,—namely, ϕ Davis — ϕ Smith $= +0''.10$. Upon the introduction of corrections based upon this assumption the residuals for Gaithersburg, and also for Cincinnati, were reduced to the same order of magnitude as those of the other stations. The difference between the results obtained by two observers lies perhaps not so much in the bisections of the stars as in the general handling of the instrument, especially, in the opinion of the reviewer, in the manipulation of the levels.

The final values of x and y give the motion of the pole as represented in the first part of the curve of Figure II, reprinted from these *Publications*,[1] and showing also the motion of the pole as obtained from subsequent observations up to the beginning of 1906.

It is not possible to decide from the data at hand whether or not the values of z derived for these stations hold also for other latitudes. The question can be most easily decided by establishing latitude stations in the southern hemisphere, and this has now been done. Three explanations are offered by Dr. ALBRECHT in regard to the term z—anomalous refraction, a north and south oscillation of the center of gravity of the Earth, the effect of the neglected annual parallax of the fixed stars. The values of z for the six different stations were found to be practically the same, so that the hypothesis of anomalous refraction seems to be excluded.

Volume II.—The second volume contains the presentation of all the observations made between 1902, January 5th, and 1905, January 4th. The treatment in this volume is in all

[1] Vol. XVIII, No. 111, p. 315.

respects similar to that given in Volume I, except that the section on the description of the observatories is omitted and a section is added at the end under the heading, "Derivation and Discussion of the Results of the Refraction Pairs." It

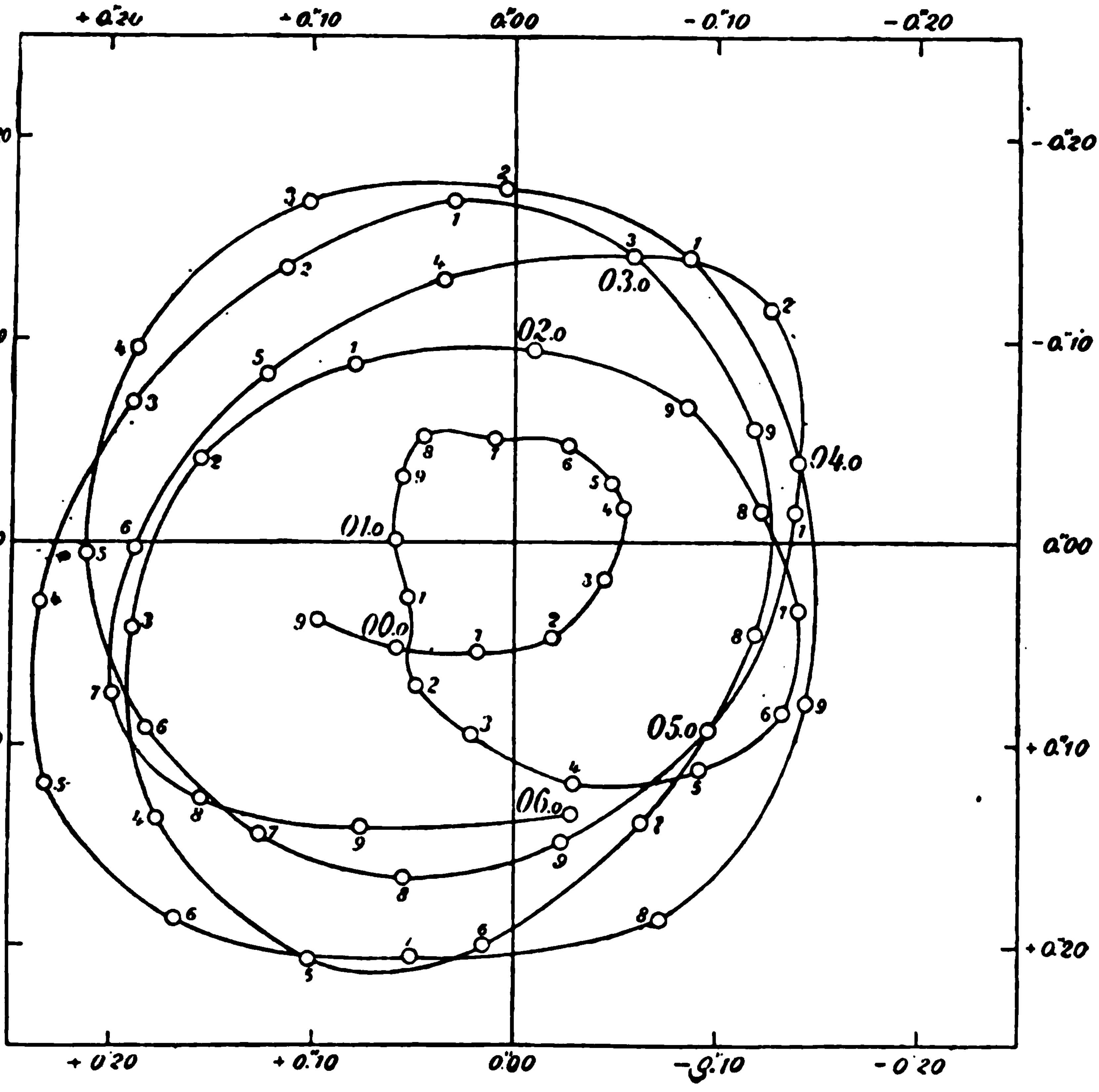


FIG. II.

is intended to call attention here only to those points at which something new is brought out in the second volume.

Additional observations were made at all of the stations for values of one revolution of the micrometer-screws, and an attempt was made to determine the temperature coefficients. As before stated, these were determined at all of the stations except Carloforte and Ukiah, where the range of temperatures is not sufficiently great to enable a good determination to be

made. Since all of the instruments were made by one maker, after the same pattern, differing only in size, it was decided to assume that the temperature coefficient was the same for all. From the observations for the four instruments for which determinations have been made, the weighted mean temperature coefficient, the change per degree centigrade per second of arc of the micrometer-screw, was found to be —0.0000259, and the resulting values for the six screws are then easily found. Before the final results for Volume II were worked out, corrections to the observed values of one revolution of the micrometer-screws were determined from the latitude observations themselves. These corrections lie between —0.0009, for Gaithersburg, and —0.0251, for Tschardjui.

The total number of observations obtained during the period under consideration in the second volume is 36,173. The percentage of nights upon which observations were made is 46.5, almost exactly the same as during the period covered by Volume I. There was an increase in the percentage at four of the stations and a decrease at Gaithersburg and Cincinnati. The percentage at Carloforte increased from 70 to 73.

During the interval under consideration, 1,096 days, there were only fourteen evenings on which observations were obtained at all six stations, and on three of these only one pair was obtained at some stations. There was not a single evening on which a complete programme was obtained at all six stations, and by looking back into Volume I it is found that there has not been a single night, from the time the last station started, 1899, December 16th, to 1905, January 4th, 1,846 nights, upon which a complete programme was obtained at all six stations.

This seems a little strange at first thought, but a simple computation according to the principles of probability will show that we are here dealing with a very rare event. Let us ask, first, What is the probability of obtaining at least some observations at each station on the same night? If we assume that observations are made on the average on fifty per cent of the nights, then the probability of obtaining observations at any one station on any particular night will be one half, and manifestly the probability of obtaining observations at two stations on the same night will be $\frac{1}{2} \times \frac{1}{2}$, or $\frac{1}{4}$, and the probability of obtaining observations at three stations on the

same night $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, and the probability of obtaining observations at six stations $(\frac{1}{2})^6 = \frac{1}{64}$. Observations would therefore be made at all six stations on the same night on an average of once in every sixty-four nights. Our assumption, however, that observations are made upon fifty per cent of the nights is somewhat in error, the true percentage being almost exactly 46.5. The probability of this event occurring would be therefore $(\frac{465}{1000})^6$ which equals $\frac{1}{99}$. This event would occur on an average therefore of once in every ninety-nine days, or nineteen times during the 1,846 days under consideration.[1] This result is in exact agreement with the observed number: there were five such events during the period covered by Volume I and fourteen during the period covered by Volume II. (*r*)

Let us now ask, What is the probability of obtaining a complete night's work at all six stations on any particular night? The ratio between the number of complete nights and the total of nights observed is not given in the volumes, but it is probably not far from one half. At Ukiah about sixty per cent of the nights upon which observations are made are complete, but the percentage is known to be less at some of the other stations. If now we assume that observations are made upon fifty per cent of the nights, and fifty per cent of these are complete, then the same kind of reasoning that was used before will bring us to the conclusion that the probability of the occurrence of the event under consideration is $(\frac{1}{64})^2 = \frac{1}{4096}$. That is to say, a complete night's work will be obtained at all six stations on an average, in round numbers, of once in every 4,000 nights, or once in about eleven years, so that it is not at all surprising that this rare event did not occur at all during the first five years of observations. (*r*)

The mean errors of a single determination of the latitude are practically identical for all stations except Carloforte, which seems to show that as accurate observations can be made with the small instruments at Tschardjui and Cincinnati as with the larger ones. The observations made at Carloforte stand in a class by themselves, as far as accidental errors go, these being distinctly less than at the other stations, probably largely

[1] The exact method of computing this probability is, of course, to take the product of the six separate probabilities rather than the sixth power of the average probability. The result comes out sixteen, rather than nineteen.

due to the favorable meteorological conditions. An examination of the curves represented in Figure 3 shows, however, that notwithstanding the small accidental errors and the large number of observations obtained at Carloforte the final results for this station are not as accurate as for some of the other stations,—Mizusawa, for example,—where the taking of ob-

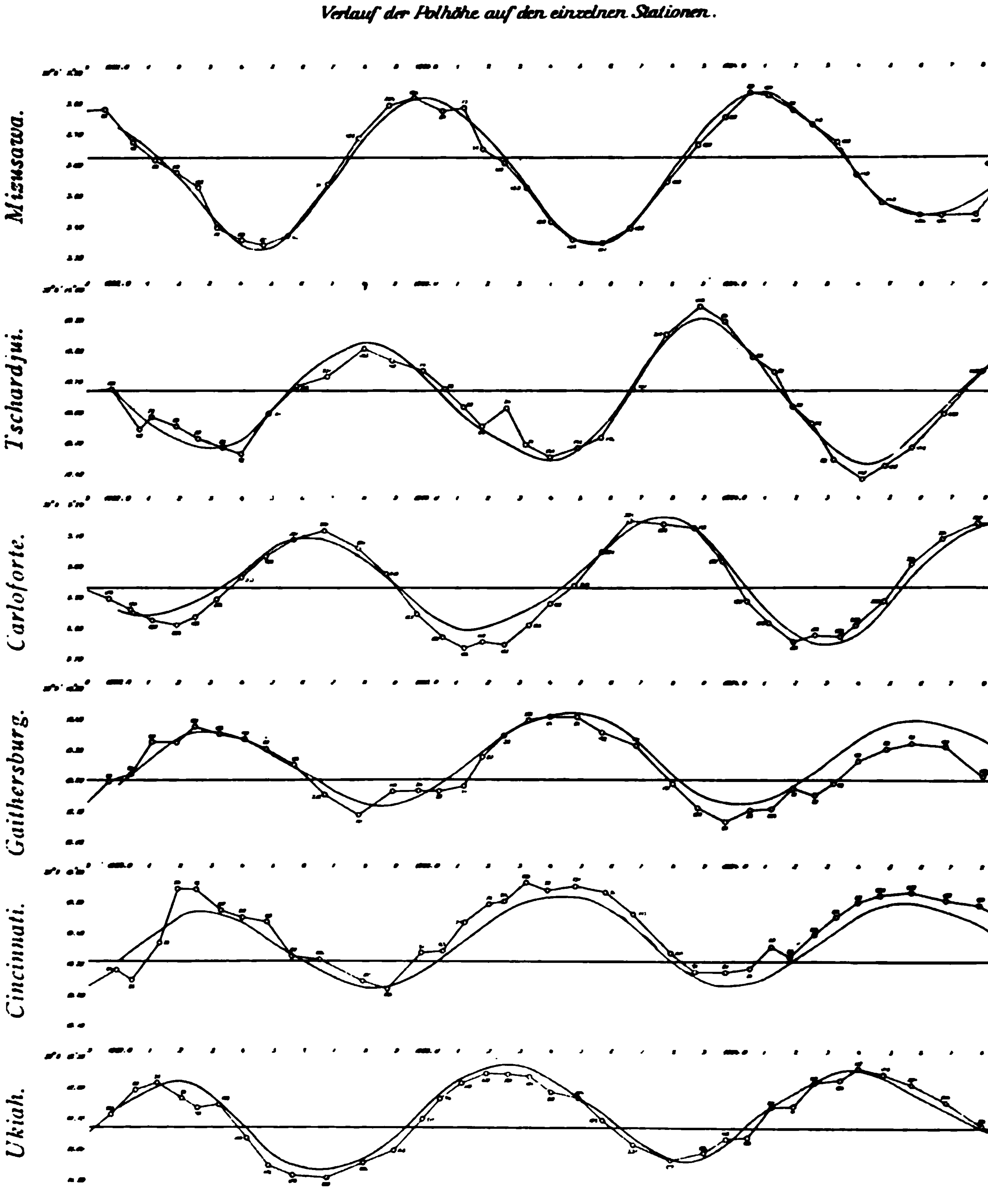


FIG. III.

servations is often badly interfered with on account of clouds or fog. Nearly twice as many observations are obtained at Carloforte as at Mizusawa, and this is a good illustration of the precept that little or nothing is to be gained by increasing beyond a certain moderate amount the number of observations made with the same instrument under similar circumstances. Perhaps just as good results could be obtained by limiting the number of observations at each station to 1,200 or 1,500 a year. (*r*)

In explanation of Figure III it should be stated that the small circles represent the average observed latitude for certain intervals, the small numbers adjacent to the circles indicating the number of observations entering into the average. After the results were all combined and the most probable values of x, y, and z were obtained from the least-square solutions, as already explained, the values of x and y were computed for each station at certain times and the results plotted on the same figure with the observed curves, producing the smooth curves of Figure III. The amounts by which the circles depart from the smooth curves, the residuals, are probably very close to the true errors of observation, and that station in which these residuals are the smallest has, of course, procured the best results.

The "closing errors" vary so much more in the different years for the same station than should be expected from the accidental errors, that it seems necessary to conclude that these differences cannot be all laid up to an erroneous value of the aberration constant. It would be necessary to assume the constant of aberration equal to $20''.541$ in order to completely explain away the closing errors. The differences are perhaps due to meteorological causes,—a very handy explanation.

The quantities z, as derived in the second volume, show a tendency toward a change in a positive direction, which presumably is due to uncertainties concerning the knowledge of the proper motions of the stars observed. An average change of $+0''.016$ a year in the proper motions would cause the positive tendency in z to disappear. The evidence seems to show that we have in this quantity z a term of constant amplitude and a period of a year. The observations thus far, however, give no indication of the cause of this term.

Volume II is concluded with a discussion of the results obtained from the observations of pairs at large zenith-distances, the so-called refraction pairs. Several hypotheses concerning abnormal refractions were made, but no very definite conclusions concerning them could be drawn from the data at hand. Without taking up the details it is perhaps sufficient to state the general conclusion reached by the authors, and that is, that observations at 60° zenith-distance provide no evidence whatever from which conclusions can be drawn regarding refractive perturbations at small zenith-distances. The observation of refraction pairs was therefore discontinued at the beginning of 1906.

SIDNEY D. TOWNLEY.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE RESULTS OF AN EFFORT TO DETERMINE MOTION WITHIN THE SOLAR CORONA.[1]

The existence of material in the corona, at various distances from the Sun, implies that it has come from somewhere, no doubt very largely, or even almost exclusively, from the Sun itself. The changed coronal forms and structures observed at different eclipses are further evidence that motion occurs. Is the material moving out from the Sun, or toward the Sun, or both? Accurate observational knowledge on this subject is very meager.

At the eclipse of 1901, favorable conditions existed in the corona for determining velocities. Measures of short exposure negatives taken near the beginning and end of totality by the Crocker Expedition to Sumatra showed no displacements of coronal masses in the interval of a little more than five minutes.[2]

Considering the accuracy of measurement, a velocity of twenty miles per second across the line of sight should have been detected with certainty, and motions should have been suspected had they been as great as twelve or fifteen miles per second.

The unusually favorable eclipse of August 30, 1905, afforded a hope that large-scale photographs of the corona secured in Labrador, Spain, and Egypt, or in two of these countries, would enable us to detect changes in the coronal structure occurring in the long intervals between the times of totality in those countries. Such photographs were obtained by the Crocker expeditions to Spain and Egypt, cloudy weather having prevailed in Labrador. The Spanish plates were secured by Messrs. CAMPBELL and PERRINE, with the assistance of Dr. R. S. DUGAN and Professor FELIPE LAVILLA; and the

[1] From *Lick Observatory Bulletin* No. 115.

[2] *Lick Observatory Bulletin*, Vol. I, 152, 1902.

Egyptian plates by Professor HUSSEY, with the assistance of the late Professor ROBERT H. WEST and Mr. H. T. R. DRAY. Totality occurred seventy minutes later in Egypt than in Spain.

We have made careful comparison of the coronal images obtained at the two stations. A number of fairly well-defined nuclei existed both east and west of the Sun. Details of structure within the nuclei appeared to change, but the nuclei as a whole seemed to remain in the same positions. Measures of great accuracy cannot be made, principally because the poorer seeing in Egypt affected the definition; but we are able to say that the masses in question could not have moved so much as one mile per second during the interval of 4,200 seconds. Greater speeds might well have occurred within the principal coronal streamers, or within some of the arched forms which inclose prominences, without our having detected them; for their structure is quite uniform, and well-defined nuclei are absent. Thus, in the structures where higher speeds should perhaps be most naturally expected, photographic methods have little chance to detect them. However, it is not improbable that at some future eclipse well-defined nuclei in coronal streamers will exist and be recorded at two or more stations.

Our result is in harmony with ARRHENIUS'S view of coronal origin: "It is very probable that those drops for which gravitation is just compensated by the pressure of radiation will be the chief material of the inner corona. For drops of other sizes are selected out, the heavier ones by falling back to the Sun, the lighter ones by being driven away by the pressure of radiation, so that the drops which, so to say, swim under the equal influence of gravitation and pressure of radiation will accumulate in the corona."[1]

Assuming that motions of appreciable size exist within the corona, it should be said that the spectrographic method of determining them is unpromising, for several reasons. The exposures are from necessity short, and the coronal light is intrinsically weak. The brighter parts of the corona radiate light forming a continuous spectrum, neglecting the almost insignificant component which gives rise to bright lines, and the relatively small quantity of reflected photospheric light.

[1] ARRHENIUS, *Lick Observatory Bulletin*, Vol. II, 190, 1904.

Spectrograms of the middle and outer corona, obtained with a relatively wide slit and low dispersion, record the Fraunhofer lines but faintly. A spectrogram of good strength would probably be difficult and uncertain in interpretation, as the slit of the spectrograph would receive light from streamers which radiate in a variety of directions from the Sun. Recalling that a reflecting particle moving directly from the Sun toward the observer will not displace the spectrum lines at all; that a reflecting particle moving directly away from, or directly toward, both Sun and observer, will give double displacement of the lines toward the red or toward the violet, respectively; and that the coronal light falling upon the slit is from particles possessing a great variety of motions between these limits; the complexity of the result is evident.

All the spectrographic measures of motion within the shallow gaseous stratum giving the bright lines are likewise in accord with ARRHENIUS's theory.

W. W. CAMPBELL,
C. D. PERRINE.

March, 1907.

NOTE ON A DISTURBED REGION IN THE CORONA OF AUGUST 30, 1905.[1]

The large-scale photographs of the corona of August 30, 1905, secured by the Crocker expeditions to Spain and Egypt, show an extensive region in the southeast quadrant composed of prominent streamers which appear to radiate from a common point. The space-form of this region seems to be approximately conical. The apex of the cone, projected upon the photographic plate, is some distance within the Sun's limb. The apex no doubt is in or near the photosphere, and the apparent axis of the cone is directed radially out from the Sun's edge. This conical volume is similar to but not so prominent as that recorded in the corona of May 18, 1901.

The chromospheric layer in the region crossed by these projected streamers is not very deep, nor does it show special activity. The streamers probably originate far from the limb; but whether on the nearer or further hemisphere of the Sun is uncertain. The estimated points of intersection of the streamers (produced) were marked on the glass side of the Spanish negatives, Nos. 2 and 7, which were exposed at about 8^s and 3^m 16^s, respectively, after the beginning of totality.

[1] From *Lick Observatory Bulletin*, No. 115.

The positions of these points were measured independently by the writers, as follows:

	Position angle from Moon's center.	Distance from Moon's limb.	Observer.
Negative No. 2	131½°	3′.24	W. W. C.
Negative No. 7	133½	3 .24	W. W. C.
Negative No. 2	132	2 .97	C. D. P.
Negative No. 7	132½	3 .11	C. D. P.

Referring these positions to the center of the Sun we have:—

Co-ordinates of Apex of Disturbed Area.

	Position angle from Sun's center.	Distance from Sun's center.	Observer.
Negative No. 2	134°	12′.78	W. W. C.
Negative No. 7	131½	13 .68	W. W. C.
Negative No. 2	134	12 .51	C. D. P.
Negative No. 7	131	13 .98	C. D. P.

An examination of the photographs of the Sun taken at Mt. Hamilton on this date shows a spot of medium size, surrounded by faculæ, in the southeast quadrant, near the Sun's limb. The following position was determined from the negative exposed at 4^h 49^m G. M. T., August 30th, or 3^h 34^m after the coronal photographs were made in Spain.

Position angle of spot.............	140°
Distance from Sun's center........	12′.67

The series of photographs of the Sun taken at Mt. Hamilton for study in connection with eclipse problems extends from August 23d to September 11, 1905, inclusive. During this interval there was no other spot in the southern hemisphere.

The lack of agreement in position of the apex of the disturbed region and the sun-spot at the time of the eclipse, taken in connection with the low velocities already found for coronal matter, suggests that an eruption (due to volcanic, radiation-pressure, or other forces) took place at a considerable time previous to the eclipse. It becomes, therefore, of interest to ascertain the position of this spot group when it was on the opposite side of the Sun at about the same distance from the limb as the apex of the disturbance, and also its similar positions an entire revolution before the eclipse. The position-angles of the spot when at 2′.6 from the Sun's eastern limb have been determined as follows:—

1905.	July 28	122°	Farther side of Sun.
	Aug. 3	132½	Nearer side of Sun.
	Aug. 24	129½	Farther side of Sun.
	Aug. 30	140	Nearer side of Sun.

It is a question whether such disturbances of coronal matter have their origin in sun-spots or in the faculæ surrounding the spots. It would be interesting to know the times of greatest activity of the spot group in question, but the history of its development is not known to us. The most probable date of the disturbance was August 3d, when the sun-spot was on the nearer side of the Sun. On that date the spot had the same position as the apex. On August 24th, with the spot on the farther side of the Sun, the position-angles of the spot and apex differed 3°.

The form of structure within the disturbed region may be divided roughly into two classes: long, slightly curved streamers, and flocculent masses. The streamers contain no condensations or other details of structure capable of accurate measurement, as a basis for determining the velocities of the matter composing them. If the forms of the streamers are functions of the velocities within them, as considered by Professor SCHAEBERLE, the speed in question would be as great as several hundred miles per second.

A determination of the velocities of some of the flocculent masses near the limb, on the assumption that August 3d was the date of their ejectment, gives a value of 700 feet per second as the minimum radial speed. The masses farther from the limb would require velocities perhaps five times as great in order to carry them to their positions at the time of the eclipse. These results are in accordance with the conclusions based on velocity determinations during the interval of seventy minutes between the occurrence of the eclipse in Spain and Egypt. This determination showed that the velocity of the flocculent masses could not have been over one mile per second.

April, 1907.

W. W. CAMPBELL,
C. D. PERRINE.

RESULTS OF THE SEARCH FOR AN INTRAMERCURIAL PLANET AT THE TOTAL SOLAR ECLIPSE OF AUGUST 30, 1905.[1]

Owing to the existence of thin clouds during the eclipse of 1901 in Sumatra, the search for an intramercurial planet was

[1] Abstract from *L. O. Bulletin*, No. 115.

not as complete as desired. It was made practically certain that there was no body as bright as the 5th magnitude in the region where such a planet would probably be, if one existed.[1]

The eclipse of August 30, 1905, offered unusual advantages for continuing the search. It was possible to occupy three widely separated stations; the eclipse came at a season of the year when the chances for clear weather were excellent at two of these stations, and the duration was longer than the average.

The value of observations at two or three stations, in case a planet should be found, would be very great, for they would enable some idea of the orbit to be obtained. With an observation at only one epoch, nothing of the orbit could be learned, and subsequent re-observation would be very difficult. In any case, the determination of the orbit of such a body, from the infrequent observations that could be secured at eclipses, would present unusual difficulties.

It was therefore planned that each of the three expeditions, despatched through the generosity of Mr. WM. H. CROCKER, should be equipped with four photographic telescopes designed for efficiency in this problem.

With a few minor exceptions, the plans for securing the necessary photographs at each of the three stations were similar to those of 1901, which are fully detailed in *L. O. Bulletin*, No. 24. The only exceptions of importance were the restriction of the field to be searched, and the taking of the duplicate exposures at different times. The fields covered were $29° \times 9°$ in the Spanish cameras, and $25° \times 8\frac{1}{4}°$ in the Labrador and Egypt cameras, the longer axis being parallel to the Sun's equator, as in 1901. The Sun was in the center of these regions.

The programme was carried out as planned at Alhama, Spain, and at Aswan, Egypt, although at the Spanish station there were thin clouds during all of totality. The four cameras at Cartwright, Labrador, had been made ready by Dr. CURTIS, but unfortunately the sky was densely clouded, and no observations were possible.

A hasty examination of some of the Spanish plates, at the station, revealed so few star images that the work was discontinued until the return of the expedition to Mt. Hamilton.

A careful examination revealed the images of thirty-six stars

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[1] *L. O. Bulletin*, Vol. I, 183, 1902.

on the Spanish plates and nineteen stars on the Egypt plates. The fewer stars on the Egypt plates is explained by adverse conditions which overbalanced the effect of the thin clouds at the Spanish station.

All of the objects found were identified as known stars. The average faintest visual magnitude of the stars shown is 8.0. Assuming that the average planetary body would be one magnitude fainter photographically than the faintest stars on the plates, then any planet of 7.0 visual magnitude should have been recorded on our photographs. This conclusion is somewhat more far-reaching than could be drawn from the 1901 eclipse results and tends to confirm the belief that some other explanation must be sought for the peculiarities in the motions of *Mercury*.

The recent investigations of SEELIGER on the effect of the matter concerned in the zodiacal light upon the inner planets seem to show that the observed outstanding perturbations in the motions of *Venus* and *Mars*, as well as those of *Mercury*, can be sufficiently accounted for upon a reasonable assumption of the distribution of such matter about the Sun. Should this explanation be confirmed, the only further need to continue the intramercurial search will be for the purpose of determining whether there are *any* asteroidal bodies in that region. A considerable number of such bodies might exist without their combined mass being sufficient to produce appreciable disturbances in the motions of the planets.

C. D. PERRINE.

NOTE ON COMET *b* 1907 (MELLISH).

A telegram announcing the discovery of a new comet by Mr. MELLISH, at Madison, Wisconsin, was received here on the afternoon of April 15, 1907. Observations were secured by the writer with the 12-inch telescope on the nights of April 15th, 16th, 17th, and 29th, and with the 36-inch on April 30th and May 7th. On the first three nights the comet was visible in the 3-inch finder, though faint on the third night on account of increasing moonlight. It was, however, a difficult object to measure because of its diffuseness and irregularity of outline. Examination with the 36-inch telescope on April 16th showed a broad fan-shaped tail in the south-preceding quadrant that could be traced about 6′ from the coma, which

appeared to be roughly circular and less than 2′ in diameter. There was no well-defined condensation.

By May 7th the comet was too faint to measure with the 12-inch telescope. A rough comparison with the ephemeris in *A. N.* 4172 gives the residuals (O – C) for May 7th, + 18^s and + 1′.5.

R. G. AITKEN.

May 24, 1907.

VISUAL OBSERVATIONS OF COMET 1905 IV.

A note in No. 113 of these *Publications* (p. 88) calls attention to the reobservation, photographically, on March 21, 1907, of this comet, which was originally discovered by KOPFF in March, 1906. Unfavorable weather conditions prevented my looking for the comet with the 36-inch refractor until the night of April 20, 1907, when it was readily seen. Though it was hardly as bright as a 14th-magnitude star, it was not a very difficult object to measure, because it had a well-defined nucleus of about 15½ or 16th magnitude.

A second observation was secured on May 4, 1907, and a comparison of the two with WEISSE's ephemeris in *A. N.* 4166 shows that the observed motion is slightly more rapid than the predicted.

R. G. AITKEN.

May 24, 1907.

NOTE ON COMET *a* 1907 (GIACOBINI).

From four observations (March 9th, by GIACOBINI, at Nice; March 13th, April 3d, by FATH, at Mt. Hamilton; April 9th, by AITKEN, at Mt. Hamilton) a second orbit of Comet *a* 1907 has been computed under the direction of Professor CRAWFORD. The fourth observation was introduced into the computation by the formation of a fictitious third position based on the two April observations.

The four observations are satisfactorily represented by a parabola. The inclination of the plane of the orbit to that of the ecliptic is 141° 39′; the longitude of the ascending node is 97° 39′; the longitude of perihelion is 54° 21′. The perihelion distance is 2.05 astronomical units, and the time of perihelion passage is March 19, 1907. The elements and an ephemeris extending to the end of May are published in *Lick Observatory Bulletin*, No. 113. The comet is moving away

from both the Sun and the Earth, and it is following the ephemeris very closely.

STURLA EINARSON,
A. ESTELLE GLANCY,
ALICE JOY.

BERKELEY ASTRONOMICAL DEPARTMENT,
May 19, 1907.

NOTE ON COMET *c* 1907 (GIACOBINI).

A preliminary orbit of Comet *c* 1907 has just been completed as this number of the *Publications* is going to press. The three observations used were made June 1st, 3d, and 4th, by GIACOBINI at Nice, HAMMOND at Washington, and AITKEN at Mt. Hamilton, respectively. The elements and an ephemeris are given in *Lick Observatory Bulletin*, No. 116. The observations are represented by a parabola. The inclination of the orbit plane to the ecliptic is 16°; the longitude of the ascending node is 161°. It was nearest to the Sun on May 27th, at which time it was 117,000,000 miles distant. The comet is faint and is receding from both the Earth and the Sun. At present it is east of the sickle in *Leo*. It is traveling toward *β Leonis*, and on June 21st will be about 5° due north of it.

STURLA EINARSON,
ESTELLE GLANCY.

BERKELEY ASTRONOMICAL DEPARTMENT,
June 5, 1907.

PLANS FOR OBSERVING THE TOTAL ECLIPSE OF JANUARY, 1908.

Arrangements have been completed to dispatch an expedition from the Lick Observatory to observe the total solar eclipse of January 3, 1908. The Moon's shadow will cross the central Pacific Ocean from west to east, and pass over only two known islands. One of these is Flint Island, in longitude 151° 48′ W. and latitude 11° 26′ S.,—that is, about 390 miles northwest of the island of Tahiti.

The eclipse will occur at 11:18, local mean time, with the Sun at zenith-distance 15°. The duration given by the American Ephemeris will be $4^m 6^s$.

The generosity of Mr. WILLIAM H. CROCKER has made possible the sending of the expedition.

The expedition will sail from San Francisco on November 22d for Tahiti. The problem of transportation from Tahiti to Flint Island and return was a difficult one, but the interest of the Navy Department of the United States Government was enlisted, and the U. S. gunboat "Annapolis" has been detailed to meet the expedition at Tahiti, transport it to Flint Island,

re-embark the expedition after the eclipse, and return it to Tahiti. The "Annapolis" is stationed regularly at Pago-Pago, island of Tutuila, and will be in personal command of his Excellency, Governor MOORE, of Tutuila, while on eclipse duty.

A later statement will describe the personnel and scientific plans of the expedition.

It seemed to me very important that the scientific programme should include a bolometric survey of the solar corona, similar to that inaugurated by Professor ABBOT at the eclipse of 1900. There is certainly no one more competent to undertake this survey than Mr. ABBOT himself. Accordingly, I brought the subject and the arrangements outlined above to the attention of Secretary Walcott of the Smithsonian Institution and Director ABBOTT of the Astrophysical Observatory of the Institution, and they have been so good as to plan for an expedition to secure the bolometric observations. The two expeditions are essentially independent, scientifically, but are united in traveling and subsistence arrangements.

W. W. CAMPBELL.

CHANGES IN THE LICK OBSERVATORY STAFF.

Mr. JAMES D. MADDRILL, Fellow in the Lick Observatory during the past four years, received the degree of Doctor of Philosophy from the University of California in May, 1907. His thesis relates to a photometric and spectrographic study of a number of well-known variable stars of the δ *Cephei* type. An abstract of the thesis will be found in a later number of these *Publications*. Dr. MADDRILL has been appointed astronomer in charge of the International Latitude Observatory at Ukiah, California, in succession to Dr. S. D. TOWNLEY.

Mr. J. C. DUNCAN, former Fellow in the Lowell Observatory, and at present Instructor in Mechanics and Astronomy in the University of Indiana, has been appointed Fellow in the Lick Observatory for the year 1907-1908.

W. W. CAMPBELL.

APPLICATIONS.

Applications are desired for the position of Assistant in the Lick Observatory, and for the position of Fellow in the Lick Observatory. For particulars, address The Director.

W. W. CAMPBELL.

GENERAL NOTES.

Mutual Occultations and Eclipses of the Satellites of Jupiter in 1908.—At the meeting of the Royal Academy of Sciences of Amsterdam on October 27, 1906, Professor J. A. C. OUDEMANS presented a paper on "The Mutual Occultations and Eclipses of the Satellites of *Jupiter* in 1908." A short account of the paper may be of general interest, as the phenomena can be observed by any one possessing a telescope.

The orbits of the four larger satellites of *Jupiter* lie in approximately the same plane. When the Earth is in or near this plane the satellites would appear to move forward and backward along a straight line, thus occulting one another in passing. In the same way, when the plane of the orbits passes through the Sun, there would be mutual eclipses of the satellites. The orbital plane passes through the Earth and the Sun twice in each revolution of the planet, so that these phenomena occur at intervals of about six years. The plane passes through the Sun on April 25, 1908, and through the Earth on July 8th of the same year, so that near these times the respective observations may be made. Some difficulty may be experienced in making the observations near the latter date as *Jupiter* will be at a low altitude, passing to conjunction with the Sun on August 17th.

Up to the present time but few such occultations have been observed, and there is only a single recorded instance of mutual eclipse. For this reason the observations of next year will have a special interest, and their value will lie in furnishing data to correct the elements of the satellite orbits. If these orbits all lay in exactly the same plane, mutual eclipse would occur at each heliocentric conjunction of two satellites near the time named, and similarly mutual occultation at each geocentric conjunction. As this, however, is not the case, some of the conjunctions will occur without bringing about either eclipse or occultation. In the latter case those using micrometers can make observations of value by measuring the difference in declination at the time of conjunction.

The following list is taken from a table given by Professor OUDEMANS, and *contains the* occultations and eclipses visible

at the Lick Observatory. This will serve for the Pacific Coast States. In observing it will be well to begin before the computed time and watch the progress of the phenomenon as the times given are for central eclipse or occultation.

Time of Eclipse. 1908.		Pacific S. T.	Eclipsed Satellite.	Eclipsing Satellite.	Direction from *Jupiter*.
April	2	$10^h\ 3^m$	I	III	East
	3	8 26	IV	I	West
	4	8 52	IV	II	East
	4	9 21	I	II	East
	5	11 56	III	II	West
	6	12 12	III	I	East
	9	12 52	I	III	East
	11	7 42	II	IV	East
	11	11 43	I	II	East
	11	12 24	I	IV	East
	22	7 13	IV	II	East
May	1	9 5	II	III	West
	1	10 43	II	I	East
	5	9 57	III	II	East
	6	8 38	I	II	East
	10	8 41	I	II	West
	11	7 26	III	II	West
	13	11 31	I	II	East
	17	8 9	I	II	East

Time of Conjunction. 1908.		Pacific S. T.	Occulted Satellite.	Occulting Satellite.	Direction from *Jupiter*.
May	31	$8^h\ 46^m$	I	II	East
June	8	7 57	IV	II	West
	9	9 18	III	I	West
	29	7 56	I	II	West
July	11	6 57	II	I	West

March 7, 1907. E. A. FATH.

Recent Double-Star Observations.—In Part 3 of Volume X of the *Publications* of the Washburn Observatory, Professor GEORGE C. COMSTOCK publishes the results of his observations of double stars in the years 1897-1906, made with the 15-inch refractor. The measures are arranged in the same form as those previously published by the same observer in Part 1 of Volume X, and constitute with them a homogeneous series.

It is a pleasure to examine this publication, for the observing list has been carefully selected, including only stars in need of measures; the stars have been observed systematically, and the results are arranged in convenient form for the use of investigators, with no superfluous matter. It is to be hoped that his many other investigations will not prevent Professor COMSTOCK from continuing with his double-star observations.

A volume of quite different character is one entitled "Measures d'Etoiles Doubles faites a l'Observatoire de Chevreuse de 1904 a 1906, par MAURICE FARMAN." The exterior of the volume leads one to infer that M. FARMAN was a most industrious observer, for it is a quarto publication of 128 pages. Examination shows, however, that M. FARMAN'S own observations occupy only one line for each star, the remaining lines—half a column in many cases—being devoted to a résumé of other observers' results between the years 1875 and 1895. As the observing list is drawn almost exclusively from the lists of STRUVE, OTTO STRUVE, and BURNHAM, of which we possess catalogues giving practically complete histories of each star to the present time, it would seem that the space thus occupied in the present volume could have been used to better advantage by giving the observer's own results in more detail. As it is, he gives only the distance, angle, and date, without any information as to the number of nights the pair was observed, the atmospheric conditions, the hour-angle, or the accordance of the measures. It is stated in the introduction that each position-angle is the mean of five settings, and each distance the mean of ten double-distance measures, and it is perhaps to be inferred that each star was observed on one night only. The measures were made with a refractor of $0^{m}.24$ aperture, and an eye-piece magnifying about 500 diameters. R. G. A.

Eros Comparison-Stars and the Magnitude Equation.—In Number 111 of these *Publications* a brief note was printed calling attention to Dr. FRITZ COHN'S investigation of the reference-stars used for the observations of *Eros*. Dr. COHN concluded that the photographic determinations of the positions of these stars at several observatories show a decided magnitude equation. In a later number of the *Astronomische Nachrichten*, Professor HINKS, of Cambridge, England, who has made a very thorough study of the *Eros* comparison-stars,

controverts this conclusion and gives his reasons for thinking that whatever other systematic errors may inhere in the photographic method, these particular observations are free from this special error. A very interesting discussion of the whole question has thus arisen, and a number of articles on the subject may be found in the *Astronomische Nachrichten*, the *Monthly Notices R. A. S.*, and other journals, the outcome of which cannot yet be stated.

It has long been known that practically every meridian observer has a personal equation due to magnitude,—that is, that he observes the transit of bright stars relatively too early as compared with the transit of fainter stars. Careful observers usually determine the amount of this equation by a series of special observations in which the transit of bright stars over half the field is observed at full brightness, and over the other half through a screen placed before the object-glass which reduces the brightness several magnitudes. It has been claimed, and Dr. COHN assumes in his argument, that observations with the Repsold self-registering transit-micrometer are free from this systematic error. The questions at issue can only be decided by careful investigations by expert observers. To the amateur perhaps the most interesting feature of the whole discussion is the minuteness of the quantities involved. It is another illustration of the high standard of precision that modern astronomy sets for its followers.

Probabilities.—If any of the readers of these notes are engaged in teaching the theory of probabilities to classes in algebra or the method of least-squares, they may be interested in the example given on page 155 of this number. The textbooks contain plenty of examples, but they are usually "made-up" ones. The writer has often thought that a few real examples, showing that actual results do come out in practical agreement with those computed by theory, would be very helpful in presenting this subject.

The computations employed in the example just referred to may be used in considering other programmes of work which are dependent upon the weather. For instance, suppose a proposition is made to establish a number of astronomical stations, widely separated along the path of totality, for the purpose of observing changes in the outer envelopes of the Sun

during the progress of a total eclipse of that body. The question naturally arises, What is the probability of the skies being clear at *all* of the stations on eclipse day? In order to give concreteness to the problem, let us suppose that it is equally likely to be clear or cloudy at any station, which is not far from the true state of affairs for most localities, then the probability of obtaining clear sky at any particular station is one half. The probability of obtaining clear skies at any two stations (separated sufficiently so as not to be under the same local weather conditions) is the product of their separate probabilities, or one fourth; of three stations, one eighth; of four stations, one sixteenth; of five stations, one thirty-second. If, then, some problem should be proposed which depends for its solution upon observations to be made at five widely separated stations upon the same day, it is seen that it would be utterly foolish to expend money for this purpose, because there would be only one chance in thirty-two of obtaining the required observations. S. D. T.

Notes from "Science."—Professor JOHN KROM REES, since 1881 professor of geodesy and astronomy and director of the Observatory of Columbia University, died on March 9th, in his fifty-sixth year. Professor REES had been ill for several years and had recently been made Professor Emeritus.

Professor HENRY DAVIS TODD, U. S. N. (retired), died at Annapolis, on March 8th, at the age of sixty-nine years. Professor TODD served through the Civil War with distinction, and became head of the Department of Physics and Chemistry at Annapolis in 1878. From 1886 to 1899 he was assistant on the Nautical Almanac, and was director from 1899 to 1900, when he retired.

The death is announced of Mr. HENRY CHAMBERLAIN RUSSELL, F. R. S., government astronomer of New South Wales since 1870, at the age of seventy-one years.

The New York Assembly on March 5th passed the Young Bill, which provides for the establishment of a nautical museum and observatory in Bronx Park, New York.

Dr. GEORGE E. HALE, director of the Solar Observatory of Mt. Wilson, has been elected one of the alumni members of the corporation of the Massachusetts Institute of Technology.

Mr. C. G. ABBOT, who had been for a number of years Sec-

retary LANGLEY's principal assistant in the Astrophysical Observatory of the Smithsonian Institution at Washington, and latterly its acting director, has been appointed director of the observatory, and Mr. F. E. FOWLE, Jr., hitherto junior assistant, has been appointed aid.

M. HENRI POINCARÈ has been appointed a member of the council of the Observatory of Physical Astronomy at Meudon, in the room of the late M. MOISSAN.

Funds have been donated by Mr. WILLIAM C. SPROUL, State Senator, of Chester, Pa., for the purchase of one of the largest telescopes on the Atlantic Coast for Swarthmore College. The exact amount of the gift, or the size of the telescope, is not known, but the instrument will be quite as efficient as the Government's telescope at Washington or the University of Virginia's telescope at Charlottesville, which are the two largest instruments in the East. The telescope will be in charge of Dr. JOHN A. MILLER, professor of mathematics and astronomy. Senator SPROUL is a member of the board of managers and has been active in the management of the institution since his graduation, in 1891.

Dr. H. C. VOGEL, of the Astrophysical Observatory at Potsdam, has been awarded the Maximilian order for art and science of the Bavarian government.

Professor DAVID P. TODD, of Amherst College, sailed on the "Panama" on May 11th for Colon, Panama, Callao, Peru, and Iquique, Chile, in charge of the Lowell Astronomical Expedition to the Andes, sent out by Professor PERCIVAL LOWELL, of Boston. Mr. E. C. SLIPHER is photographer, Mr. A. G. ILSE, of Alvan Clark & Sons, the instrument maker, and Mr. R. D. EAGLESFIELD, mechanician. The party will observe the opposition of *Mars* with the 18-inch telescope of Amherst College Observatory, and the annular eclipse of the Sun, July 10th, for Professor NEWCOMB.

Abstracts of Papers.—Two recent numbers of *Science*, April 12th and 17th, contain accounts of the meeting of the Astronomical and Astrophysical Society of America, held in New York during the last convocation week in connection with the annual meeting of the American Association for the Advancement of Science. Thirty-one papers were presented before the society and four papers upon astronomical subjects before

Section A of the Association. If we may judge from the titles, many of these papers must have been very interesting. Abstracts of most of them may be found in the numbers of *Science* just referred to.

The American Astronomer.—In a recent issue attention was called to the *Journal* of the Royal Astronomical Society of Canada, a new periodical, published bi-monthly, and similar in scope to our own *Publications,* the *Journal R. A. A.,* and others designed to extend and popularize the study of astronomy. The second number meets the expectations raised by the initial issue, and we trust the *Journal* has entered upon a long life of usefulness.

A publication of a different type is "*The American Astronomer,* an international publication for practical astronomers," published at Marlborough, Mass., of which two numbers have appeared. The object of this journal is to give prompt intelligence of items of interest to astronomers, and it is therefore the aim of the editor, WM. D. MCPHERSON, to publish as often as possible. At present the paper will appear monthly. It is an experiment worth making, and the result will be watched with interest. The subscription price is placed at $2.00 per year.

"*How to Know the Starry Heavens.*"—We are glad to note that this work on popular astronomy by one of the members of our Society, Mr. EDWARD IRVING, has been well received by the public. Very favorable comments have been printed in many journals, like the *Outlook,* that notice scientific books likely to interest the general public. Mr. IRVING'S facts are correct, his style free from technicalities, and his illustrations numerous, well chosen, and well-executed reproductions from excellent modern photographs and drawings.

NEW PUBLICATIONS.

FARMAN, M. Mesures d'étoiles doubles. 1904-06. Paris: Gauthier-Villars. 1907. 4to. VII + 128 pp. Cloth.

HAGEN, J. G. Atlas Stellarum Variabilium, Series IV. 4to. Atlas and catalogue. Cloth. 120 Marks.

HALE, GEORGE E., and KENT, NORTON A. The spectrum of the high-potential discharge between metallic electrodes in liquids and in gases at high pressures. Chicago: Publications of the Yerkes Observatory. Vol. III, Part II. 1907. 4to. 38 pp. 8 plates. Paper.

HAYNES, E. S. The variable RS *Cassiopeiæ*. Columbia: University of Missouri. (Laws Observatory Bulletin, No. 11.) 4to. 14 pp.

HILL, G. W. The collected mathematical works of. Vol. IV. Washington: Carnegie Institution. 1907. 4to. 460 pp. Paper. $2.50.

HOELLING, JOSEPH N. Untersuchungen über die Bewegung des Planeten (13) Egeria. Kiel: Astronomische Ahbandlungen, No. 12. 1907. 4to. 30 pp. Paper.

JOST, E. Untersuchungen über die Parallaxen von 29 Fixsternen. Karlsruhe: Veröffentlichungen der Grossherzoglichen Sternwarte zu Heidelberg. (Astronomisches Institut.) Band IV. 1906. 4to. 171 pp. Paper.

PICKERING, W. H. Lunar and Hawaiian physical features compared. 4to. 28 pp. 16 plates. Cloth.

SAINT-BLANCAT, D. Action d'une masse intermercurielle sur la longitude de la lune. Paris: Gauthier-Villars. 1907. 4to. 103 pp. Paper.

SEARES, F. H. Announcement of preliminary results for variable stars. Columbia: University of Missouri. (Laws Observatory Bulletin, No. 10.) 4to. 22 pp.

SMITH, C. MICHIE. Widened lines in sun-spot spectra. Kodaikanal Observatory: Bulletin No. VIII. 4to. 20 pp. Paper.

STEIN, J. W. J. A. Beobachtungen zur Bestimmung der Breitenvariation in Leiden. Haag: Annalen der Sternwarte in Leiden, Neunter Band, Heft I. 1906. 4to. 237 pp. Paper.

Conference astrophotographique internationale de Juillet 1900. Circulaire No. 12. Paris: Gauthier-Villars. 1907. 4to. (III) + (14) + (A127) + (B152) pp. Paper.

Report of the British Association for the Advancement of Science, 1906, York. London: John Murray. 1907. 8vo. cxxiv + 831 + 89 pp. Cloth.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

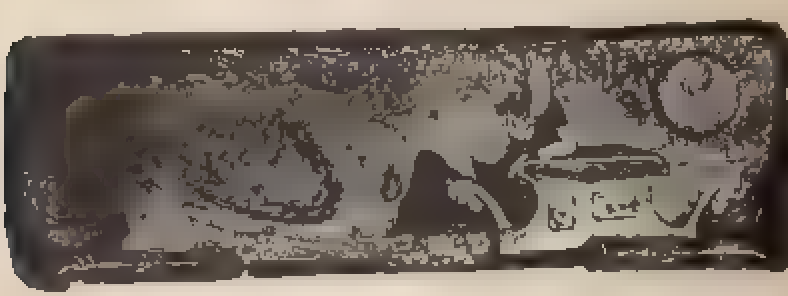
It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof-sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XIX. San Francisco, California, August 10, 1907. No. 115.

OUR DEBT TO ASTRONOMY.

By Russell Tracy Crawford.

Astronomers are so often asked questions such as "What is astronomy good for?" "Why waste your time and energy upon anything so immaterial and unpractical as astronomy?" "What good does it do to know where a comet is going?" etc., that it seems opportune and fitting to answer such questions quite thoroughly. For this reason the subject "Our Debt to Astronomy" has been chosen for this address. These questions and many others of a similar nature show how little thought is given by the general public to such matters, and how carried away they are with the intensely practical ideas of this rapidly advancing age, which seems to have emblazoned upon its banner not "Excelsior," but a glaring monogram of the United States with the curve at the bottom of the U eliminated from the picture. Among other things I hope to convince the followers of this banner of the almighty dollar that astronomy is one of its most potent aids and should therefore be one of its pets, worthy of its support.

Upon this subject Professor Young writes as follows in the introduction to his "General Astronomy":—

"At present the end and object of astronomical study is chiefly knowledge pure and simple; so far as now appears, its development has less direct bearing upon material interests of mankind than that of any other of the natural sciences. It is not likely that great inventions and new arts will grow out of its laws and principles, such as are continually arising from physical, chemical, and biological discoveries, though of course it would be rash to say that such outgrowths are impossible. But the student of astronomy must expect his chief profit to be intellectual, in the widening of the range of thought and conception, in the pleasure attending the discovery of simple law working out the most complicated results, in the delight over the beauty and order revealed by the telescope in systems otherwise invisible, in the

recognition of the essential unity of the material universe, and of the kinship between his own mind and the infinite Reason that formed all things and is immanent in them. . . .

"At the same time it should be said at once that, even from the lowest point of view, astronomy is far from a useless science. The art of navigation depends for its very possibility upon astronomical prediction. Take away from mankind their almanacs, sextants, and chronometers, and commerce by sea would practically stop. The science also has important applications in the survey of extended regions of the country, and the establishment of boundaries, to say nothing of the accurate determination of time and the arrangement of the calendar."

It is the intention here to go further than this, and to speak not only of the present, as Professor YOUNG does, but to go back to the beginning of things and to show the principal accounts in "Our Debt to Astronomy."

Let it be known at the outset that for many centuries, from the beginning of terrestrial affairs, the history of the world is practically the history of astronomy. For many centuries, we cannot say just how many, astronomy was the one and only agent to quicken the thoughts of men and to lead them to a comparatively high state of intellectual development. Place ourselves, if we can, in imagination back into the so-called prehistoric times, and it will at once be evident that the most striking phenomenon of nature—viz., the rising of the Sun, Moon, and stars in the east, their daily journeys across the sky, and their setting in the west—would be the first thing to draw thought and set active minds to speculate. Once started, the keen mind would soon find other phenomena of astronomy to work upon, and in this way was built up that foundation for the superstructure of culture and knowledge which we find in the possession of earliest historical man—our first debt to astronomy.

We find that, in the beginning of what we may call authentic history, astronomy was purely a practical science. Theoretical astronomy there was, wild as it may have been, but it was the practical side of astronomy that was most developed and cultivated. It was very necessary in those times, when agriculture was the main industry, to know when to sow the crops, and when to reap them,—in other words, a knowledge of the season was essential to existence itself. And how, indeed, was a knowledge of the seasons to be had, not only then but now, except by a careful study of the wanderings of the Sun from

its southernmost position to its most northern station, and back again, during the course of the interval of time that we call a year? Let us consider, in particular, the case of the Egyptians. Egyptian civilization would have been impossible but for the Nile floods, which appear with great regularity. The rising waters reach the region of Heliopolis and Memphis almost exactly upon the day that the Sun is at the summer solstice. It is very evident, then, that the Egyptians before us were under obligations to the astronomers of their age to inform them of the time when the Sun would be at the summer solstice. It is no wonder, then, that the Egyptians commissioned their astronomer-priests to observe carefully for the helical rising of *Sothis* or, as we now call it, *Sirius,* the dog-star, to give them the necessary datum upon which their year's material prosperity depended. As every advance in early knowledge and civilization was an essential stepping-stone to our present acropolis of culture, we of to-day owe this a second debt to astronomy.

It must ever be borne in mind that our present-day knowledge has not been attained by the spontaneous outburst of genius in a single generation, but has been built up slowly, step by step, from earliest times, each single advance being a necessary precursor of later development. HIPPARCHUS must precede PTOLEMY, and PTOLEMY must precede COPERNICUS. COPERNICUS made the way easier for KEPLER, and KEPLER in turn added the stone upon which NEWTON built, and so on. To every contributor of a stone in our Temple of Knowledge, whether it be in foundation or superstructure, we of to-day owe a debt.

Incidentally, we have a decided personal interest in the theoretical astronomy of the Babylonians, who gave us the week of seven days, with the names taken from the Sun, Moon, and the then-known five planets, *Mercury, Venus, Mars, Jupiter,* and *Saturn.* Had *Uranus* and *Neptune* been known to them, our week would have been nine days long instead of seven, with one day in nine for rest.

To astronomers and their science we owe the evolution of the ideas and conceptions of the size and shape of our globe. The earliest peoples believed the evidence of the senses, and thought that they lived upon a large flat surface. More ad-

vanced ideas were that the Earth was a truncated cone, and then a cylinder, and finally, even so early as the time of PYTHAGORAS, it was shown to be a sphere. As to its size no definite conception was had until comparatively recent times. The determination of its dimensions to-day would be impossible but for the astronomer.

Astronomy has not always advanced, but has had its setbacks, from which, however, it has nobly recovered. This brings me to speak of the retarding influence of ARISTOTLE and PTOLEMY upon the world's knowledge and culture; its overthrow brought about by astronomers, and the wonderful results therefrom—one of the greatest of our debts to astronomy.

In the third century B. C. ARISTARCHUS of Samos and others of less note had asserted that the Earth was in motion—a very advanced idea for the time; but they could not prove it. Then came a backward step, taken by PTOLEMY, who apparently proved that the Earth was not in motion, but was immovable at the center of the universe. This idea held sway for fourteen centuries, until the time of COPERNICUS. Its overthrow came at about the time of the downfall of the influence of ARISTOTLE. These two accomplishments were the most vital forces of the Revival of Learning. It has well been said that ARISTOTLE retarded the progress of the world's knowledge and culture more than any other one man. His dictum was the undisputed law in the realms of knowledge for seventeen centuries. If any one dared to present an idea contrary to ARISTOTLE the sneering question was ever ready, "Do you think you know more than ARISTOTLE?" and the investigator was completely squelched. This absolute servility to the dogma laid down by the great philosopher furnishes one of the most remarkable pictures in history. But sooner or later this had to end, and the end came with GALILEO, the astronomer. I may recount here the beginning of this end. ARISTOTLE had said that a large heavy body would fall from a given height in less time than a small light one. For seventeen centuries it had never occurred to any one to investigate experimentally the truth of this assertion, or else no one had dared to try it. GALILEO, the astronomer, however, was not content to take the word of anybody, even ARISTOTLE, upon a matter which could be proved or disproved so easily as this.

one. Dramatic indeed must have been the scene when the great astronomer mounted to the top of the leaning tower of Pisa and let fall simultaneously a large heavy body and a small light one, and great indeed must have been the astonishment of the populace gathered to witness the experiment when they beheld the two bodies falling side by side and reaching the Earth at practically the same time, demonstrating, as KIPLING puts it, that "heart-breaking power, the perversity of inanimate things." At that instant fell also the influence of ARISTOTLE in the scientific world.

COPERNICUS had just previously shown that the Earth is in motion about the Sun, and when GALILEO clinched this idea, so to speak, by turning his telescope upon *Jupiter* and there beholding the four moons revolving about the central mass, a miniature world, the revolution was complete. It is difficult for us to imagine what a convulsion must have taken place in the minds of men at that time. The Church had taught that the Earth was stationary, and even to think anything else was the greatest heresy, as it was contrary to Holy Writ. In view of this, is it any wonder that we had the Dark Ages? Because of the unswerving adhesion to dogma in those days it is, again, no wonder that the great astronomer, GALILEO, was brought before the Inquisition, tried and convicted of heresy, furnishing one of the most dramatic, almost tragic, incidents in the history of science. But the ideas once started by COPERNICUS and GALILEO soon began to spread and found firm supporters, and the world once more started on the way of progress. We cannot begin to appreciate the effects of such a revolution in the world's thought. At first sight one would say, "What a loss of importance and dignity!" We are no longer the great IT,—the center of the universe about which all else must turn, and to which all else must be subservient. But, on second thought, we would say, and do now say, "What a gain in beauty and grandeur!" We now find ourselves whirling about the great Sun in the infinite sea of ether, gazing into its immeasurable expanse. Can any one estimate the amount of dollars and cents in this debt we owe to astronomy? No; it is above dollars and cents.

Following quickly upon the steps of these two great astronomers we have KEPLER, who gave us his laws of planetary motion, by means of one of which the scientific mind was

freed from the so-called perfect path, the circle, and was introduced to the use of the general conic. His work, in turn, formed the stone upon which Sir ISAAC NEWTON built so well. It would be a long story, indeed, to recount the various debts we owe to this man, our greatest astronomer. For the more practical-minded, however, I will call attention merely to one of his accomplishments. In evolving his universal law of gravitation, and in furtherance of his astronomical investigations, it became necessary for him to invent a new branch of mathematics—namely, Calculus. Is there any one so daring as to estimate the commercial value of calculus? The idea is staggering. It is beyond human power to make the computation. Without this powerful implement, due to astronomy, what could be done in applied mechanics? Where would our sky-scrapers be? How could we build our battleships? Where would our electric-cars be? How could our enormous bridges be built?—and so on, almost *ad infinitum*.

Less than a month ago, while coming in from Oakland on the electric-car, a friend asked me the old question, in rather inelegant English, "What is astronomy good for?" Among other things I said, "I suppose you see no connection between astronomy and this electric-car?" The answer was a ready "No!" The connecting-link is this same calculus.

We find, not only in the applied sciences, but also in many of the natural sciences, higher mathematics to be an absolute necessity. And to what are the higher branches of mathematics due? The answer is, "Principally to astronomy." I wish to quote here from Dr. WILLIAM F. WHITE's article on "The Nature of Mathematical Reasoning," in No. 609 of "The Open Court." He says, "Behind the artisan is a chemist, behind the chemist a physicist, behind the physicist a mathematician." There he stops, but I now add, behind the mathematician the astronomer.

Another great debt that we owe to astronomy is one on behalf of our peace of mind. From the beginning up to the present time there have been, and now are, many people filled with superstition concerning the heavenly bodies. Thanks to astronomy, these are becoming fewer and fewer. In ancient times whole nations were thrown into a panic by an eclipse of the Sun; armies on the eve of battle were commanded to halt, with disastrous results, to await the passing of the ill-

omen of an eclipse of the Moon. Comets were supposed to be within our own atmosphere, and to bring pestilence and disease. These phenomena have been shown by astronomers to be ordinary affairs in the celestial mechanism, having no bearing upon our regular existence. Unusual conjunctions of several planets are even now by some thought to have an important bearing upon the affairs of life. Many crafty people to-day make a livelihood by imposing upon the more superstitious and easily-fooled people by casting horoscopes. One of our daily papers thinks so little of the value of its space as to give up a quarter of a column in every issue to the publication of COZETTE's horoscope for the next day.

Within the last few weeks the papers announced that a comet had been discovered by an astronomer on Mt. Ætna, which was coming directly toward us and would soon annihilate the Earth. Immediately after the appearance of this wonderful announcement this observatory had many letters of inquiry concerning it. Some people evidently believed in it, and wanted to know the exact date when the direful catastrophe would occur. Probably there will always be some who will be thus taken in, but, thanks to the teachings of astronomy, we live in practically perfect peace of mind regarding these things. Nations are no longer convulsed by an unexpected eclipse, and astronomers royal are not decapitated for failure to predict them.

A study of the simple elements of astronomy would be very beneficial to artists and writers. They often make serious mistakes through mere ignorance. It is not very uncommon to see an otherwise beautiful painting spoiled completely by a delicate crescent Moon with its horns pointing toward the Sun. A note in No. 383 of the *Observatory* calls attention to the fact that in chapter I of "Jane Eyre," by CHARLOTTE BRONTÉ, occurs this expression: "(The Moon's) newly risen crescent, attesting the hour of eventide," a statement which makes the author appear ridiculous. Many instances of this kind could be cited.

Finally we come back to Professor YOUNG's statement, to consider the present-day, all-absorbing, dollars-and-cents value of astronomy. You have all probably traveled at night, resting more or less comfortably in a berth of a Pullman attached to an express train, which in its course thunders by a freight

train on a siding. You give but little, if any, thought to it, having confidence in the men running the train. These men in turn have confidence in their running because they are running "on time." Think what it means to the railroads of the country, and to the public, to have the trains running "on time." To be able to handle the enormous traffic of to-day correct time is an absolute necessity. Where do the railroads get their correct time? Another account in our debt to astronomy.

Again, when it became necessary to run the boundary-line between Canada and the United States astronomers had to be employed. Our maps cannot be made without a knowledge of practical astronomy. Extended surveys also require a knowledge of practical astronomy.

I will call attention to one more, perhaps the greatest, commercial debt we owe to astronomy; that is, the service it renders to navigation. Were it not for the data furnished by astronomers, commerce by sea would practically stop. The sailing-master on the high seas could not determine his position, nor in what direction to head his ship in order to reach a desired harbor. Think what this means in dollars and cents, and estimate it if you can. For this one service alone the science of astronomy is worth more in dollars and cents to the world in one week than has been expended upon it since the beginning of civilization. Do you think that Great Britain, for instance, would take in exchange an amount equal to its national debt for what astronomy gives her? I answer for you, most emphatically, "No."

Even these commercial values sink into insignificance when we consider again, in general, what astronomy has done for us in giving us the laws upon which mechanics is based; in pushing mathematics to its present state of development, the effect of which ramifies rapidly; in being one of the most powerful factors in bringing us to a better understanding of nature; and in broadening our views and taking us out of the narrow confines of a little plain, immediately surrounding the Ægean Sea, and launching us into the infinite realms of space.

In conclusion, I wish to answer one more question—namely, "While some parts of astronomy may be of value, why exert so much thought and energy upon other parts which are *purely abstract* and theoretical?" The answer to this is that

we never can tell to what such abstract speculations may lead, and that, in the end, they may give us something exceedingly valuable, either in the commercial world or in the realms of culture and knowledge. A comparison with prospecting may make it clearer. The miner digs day after day with apparently no return. He may continue to do so with no result, no matter how long he labors; but, on the other hand, at any moment he may unearth a rich vein which will more than repay him for his efforts. So it was with KEPLER, when he dug through TYCHO's observations day after day with no result, until finally, after much labor and the use of an enormous store of patience, he struck the vein of planetary motion, and his wonderful laws were brought to light. It was MICHAEL FARADAY who said so well, "There is nothing so prolific in utilities as abstractions."

And now, in closing, I desire to express the hope that you who have heard what I have had to say, and those who may hereafter read what I have said, will ever feel it unnecessary to ask in inelegant English, "What is astronomy good for?"

BERKELEY ASTRONOMICAL DEPARTMENT, July 13, 1907.

THE LOST RINGS OF *SATURN*.

BY ARTHUR B. TURNER.

The Moon long since became a dead world, without air or water. The planet upon which we dwell is well advanced in its development; its surface has cooled and hardened, but it still has air and water, the great life-giving elements. We look out upon the planet *Mars* with its surface covered by canals in the struggle of the inhabitants to get water to supply their needs. But beyond *Mars*, at a distance more than nine times our distance from the Sun, there circles a world, resplendent in the making, surrounded by satellites and rings, and taking over twenty-nine years to make its majestic swing around the Sun. This orbit formed the boundary to the solar system down to the discovery of *Uranus*, by HERSCHEL, in 1781. *Saturn* has a diameter a little more than nine times that of the Earth, and makes over two revolutions on its axis in one of our days. The result of such swift rotation is to make

the planet appear perceptibly flattened at the poles when viewed in the telescope. A vast envelope of clouds surrounds the fiery ball, which is light enough to float on water.

SATELLITES AND RINGS.

Ten moons swing around this globe, obedient to its attraction, the last one having been discovered by Professor W. H. PICKERING, of Harvard. The ninth satellite—*Phœbe*—is remarkable in the fact that it disobeys the ordinary laws of solar motion by moving backwards around the planet.

But the most remarkable feature of this world—distinctive from all other celestial bodies—is the wonderful system of rings, first discovered by GALILEO, and which appeared to him as bright stars on either side of the disk. He says of his discovery: "Looking on *Saturn* within these few days I found it solitary without the assistance of its accustomed stars, and in short perfectly round—are perhaps the two smaller stars consumed like spots on the Sun; have they suddenly vanished and fled? Or has *Saturn* devoured his children?" And so this old pioneer of astronomy died without realizing that what he had discovered was one of the greatest anomalies of the

solar system. It was left for HUYGHENS, in 1655, to announce their true character.

There are three wide, thin rings surrounding the planet in the plane of its equator, and ranging from eleven thousand to eighteen thousand miles in width and about fifty miles thick. They are inclined to our path around the Sun, so that we see them at various angles as they reflect back to us the Sun's rays. It was thought at one time that they consisted of fluid or solid, but the mathematicians proved that such rings would soon fall to pieces, and that probably they consisted of swarms of particles like meteors, each particle following an independent path around *Saturn*, just as the Moon does around the Earth. By spectroscopic observations of the rings by the late Professor KEELER, it was shown that they must consist of discrete particles.

THE LOST RINGS.

The plane of these rings moves parallel to itself as they accompany the planet around the Sun, so that about every fifteen years this plane will pass through the Sun. The Earth in passing around the Sun will view the rings in varying positions. This year the plane of the rings passes through the Sun, and from April 12th to July 22d we face the unillumined side of the rings—the Sun being north and the Earth south of their plane. To us, then, the rings will appear as a black bar crossing the disk of the planet, with possibly a faint line of light where the rings extend on either side of the ball.

In 1891 the great Lick telescope failed to show any trace of the rings when in a similar position. From July 22d to October 4th the rings reappear as a narrow line of light on the two sides of the planet, as shown in the figure above. From October 4 to January 6, 1908, the Earth will be north of the plane of the rings and the Sun south of this plane, and the above phenomena will be repeated. It was this disappearing of the rings that so puzzled GALILEO.

When the rings are more favorably situated we can see the shadow cast on them by the planet, and also the disk shining through the inner dusky "crepe" ring.

COLLEGE OF THE CITY OF NEW YORK,
DEPARTMENT OF MATHEMATICS AND ASTRONOMY.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon....	Sept. 7,	1^h	4^m	P.M.	New Moon....	Oct. 7,	2^h 21^m	A.M.
First Quarter..	" 14,	7	40	P.M.	First Quarter..	" 14,	2 2	A.M.
Full Moon....	" 21,	1	34	P.M.	Full Moon.....	" 21,	1 16	A.M.
Last Quarter..	" 29,	3	37	A.M.	Last Quarter...	" 28,	11 51	P.M.

The autumnal equinox, the time when the Sun crosses the equator from north to south, is September 23d, 9 P.M., Pacific time.

Mercury is a morning star on September 1st, rising about half an hour before sunrise, too near the Sun for naked-eye observation. It is moving toward the Sun, and passes superior conjunction on September 6th, becoming an evening star. It then moves out toward greatest east elongation, which it reaches on October 23d; but as its motion carries it southward relative to the Sun, the conditions for visibility are poor, and it does not remain above the horizon as much as an hour after sunset at any time during the period. While it is still a morning star on September 3d, it is in very close conjunction with *Venus*. passing to the north of that planet 26′, less than the apparent diameter of the Sun, but both bodies are too near the Sun to be seen.

Venus, like *Mercury*, is a morning star on September 1st, too near the Sun to be seen, and passes superior conjunction. becoming an evening star on September 14th. After this date its motion relative to the Sun is eastward, and by the end of October its distance is about 12°; but it is also moving somewhat southward, and on October 31st it sets only a little more than half an hour after sunset, so that it is scarcely possible to make any naked-eye observations during the two months. This is rather a rare occurrence.

Mars is still in fine position for observation, setting about half an hour after midnight on September 1st, and shortly after 11 P.M. on October 31st. It has begun to move rapidly eastward, and during the two months' period moves 33° eastward and 8° northward from a position among the stars of the milk-dipper group in *Sagittarius* to the middle of *Capri-*

corn. On September 2d it is a little more than 1° south of *σ Sagittarii,* the right-hand star in the bottom of the bowl of the dipper, and on September 10th passes less than 1° north of *τ Sagittarii,* the left-hand star in the bottom of the bowl. It is in perihelion on the morning of September 26th. Its distance from the Earth changes from fifty millions of miles on September 1st to sixty-six millions on October 1st, and eighty-five millions at the end of the month. By September 1st its brightness is about forty per cent less than it was at its maximum, in early July, and it begins to fall off rapidly during the two months, so that at the end of October it is only one fifth as bright as it was at opposition, but it will still be bright enough to be conspicuous.

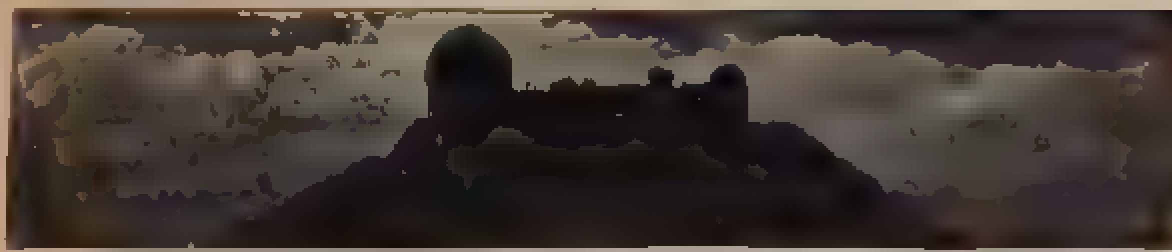
Jupiter is a morning star, rising about 2^h 30^m A.M. on September 1st, at about 1 A.M. on October 1st, and at a little before 11^h 30^m P.M. on October 31st. It is in the constellation *Cancer,* and moves about 9° eastward and 2° southward during the two months. On the morning of September 3d it makes a very close approach to the Moon, and for some places will be occulted.

Saturn is in fine position for observation throughout the months of September and October. On September 1st it rises about an hour after sunset, and comes to opposition on September 17th. On October 1st it does not set until nearly 5 A.M., and on October 31st it sets at about 2^h 30^m A.M. It is in the western part of the constellation *Pisces,* and moves about 4° westward and 2° southward. The phenomena of the rings are still very interesting. On September 1st both the Sun and Earth are below the plane of the rings, and we are therefore looking at the illuminated face. The rings appear very narrow, and continually grow narrower until about October 4th; at this date the Earth passes through the plane and we see the rings edgewise. It will take a good telescope to show anything of the rings in such circumstances. For the remainder of the year after October 4th the Sun and Earth are on opposite sides of the plane, and therefore the side facing us is the dark side. The rings widen out a little until about the end of November, and a fine telescope may show this by the curvature of the thin line of light reflected from the edge.

Uranus is in fair position for observation in the evening sky. On September 1st it sets at about 12^h 30^m A.M., on

October 1st at about 10^h 30^m P.M., and on October 31st at about 8^h 30^m P.M. Its motion among the stars is very small—a little westward until September 18th, and then about 1° eastward by the end of October. It remains in the constellation *Sagittarius*, north of the milk-dipper group, about 3° north of ϕ and σ *Sagittarii*, the stars in the bowl nearest the handle.

Neptune rises shortly after 1 A.M. on September 1st, and shortly after 9 P.M. on October 31st. It is nearly stationary in *Gemini*.



NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON COMET *d* 1907 (DANIEL).

This comet was discovered by DANIEL at Princeton on June 9, 1907. The preliminary elements by CRAWFORD, EINARSON, and MISS GLANCEY, of the Berkeley Astronomical Department, indicate that it will pass perihelion on September 4th at about half the Earth's mean distance from the Sun.

In the early part of July I observed the comet here with the 12-inch telescope, and found it to be of about the seventh magnitude and growing brighter. Photographic observations with the Crocker photographic telescope were begun on July 10th and continued every night until July 21st, after which the late setting of the Moon prevented exposures of sufficient length to be valuable. With the Moon away it was possible to obtain exposures two hours long.

The first photograph showed a tail of five or six degrees' length with two longitudinal dark lanes and several knotty condensations. The second, (July 11th) also showed condensations, but since the date of this photograph the tail has consisted of straight or slightly curved, smooth streamers. No identity could be established between the condensation of the tail of July 10th and those of July 11th, and therefore their velocity of recession from the nucleus could not be determined.

Since the photographs were begun the comet has grown rapidly brighter, and the tail has increased rapidly in length and complexity. On the night of July 20th no less than six streamers diverged from the nucleus, and these subdivided into several branches, extending about 12° from the head.

In photographic observations of comets it has been found that, as a rule, the tail changes completely between consecutive nights, so that it is desirable that negatives be made at intervals of a few hours in order that the velocity of particles within the tail may be determined. With this object in view, a second lens, of 6-inch aperture and 32-inch focal length, was mounted

beside the Willard lens. By this means it is possible to obtain two one-hour exposures each night, together with one two-hour exposure, which will show more of the faint detail. The apparatus was used in this way on the nights of July 19th and 20th. Measures made on the point of forking of the principal tail on the short-exposure plates of July 20th indicate a component of velocity of recession from the head, perpendicular to the line of sight, of about seventy miles per second. This apparent motion of the point of forking may be real, or it may be an illusion due to the closing together of the two branches of the fork, which would cause the point of separation to seem to move outward.

The comet is now of the third magnitude, and is rapidly growing brighter. Since July 17th the tail, as well as the nucleus, has been visible to the eye. An ephemeris computed from CRAWFORD's elements shows that the comet will reach its maximum theoretical brilliancy about August 20th, when it will be about twenty times as bright as on June 15th and about twice as bright as it is now. This calculation is of course based on the assumption that all of its light is reflected sun-light, and the actual brilliancy may much exceed the theoretical. At the time of perihelion the comet will be about an hour and a half west of the Sun in right ascension, and it is hoped to extend the series of photographs much further.

LICK OBSERVATORY, July 24, 1907. J. C. DUNCAN.

SPECTROGRAPHIC OBSERVATIONS OF VENUS FOR SOLAR PARALLAX.

The determination of the solar parallax by spectrographic methods has long been under consideration among astrophysicists, but until very recently it has been thought to be out of the reach of spectrographs now in use. The work of taking a series of spectrograms of stars having small latitude was begun by Sir DAVID GILL at the Cape Observatory, and is now in progress. The accuracy with which this series will determine the solar parallax has not yet been fully ascertained; at least it has not been published. Professor KÜSTNER, in an article reviewed by Dr. J. H. MOORE in Vol. 17, 197, of these *Publications*, gets a p. e. of $\pm 0.22^{km}$ for a single plate of *Arcturus;* using eighteen plates, he obtained the value $8''.844 \pm 0''.017$ for the parallax.

The measures of check-plates of *Venus,* taken with the remounted Mills spectrograph in 1904 and 1905, agreed well enough to warrant the taking of a few plates at each of two successive elongations of the planet, to see what weight a value of the solar parallax would have if determined spectrographically from *Venus* alone, and to find out what increase of power would be necessary to put this method on a par with the most accurate of those now in use.

The elements of the orbits of the Earth and the other planets are well determined, but the dimensions are relative. If at any time we can determine the absolute distance from the Earth to another planet, or measure the velocity of any planet with respect to the Earth the absolute size of the whole system can be readily found. Knowing the size of the orbit of *Venus* relative to that of the Earth, the velocity of light and a few absolute wave-lengths we can determine the solar parallax by spectrographic observations of the planet.

While the velocity of *Venus* with respect to the Earth is not so great as that of the Earth with reference to a star on the ecliptic, and while the large hour angles necessary in taking spectrograms of *Venus* are inconvenient, if not prejudicial, the brightness of the planet and freedom from unknown changes in velocity due to satellites and from small spectral variations such as may be encountered in stars, will more than counterbalance the disadvantages when we come to use a more powerful apparatus, such as we are about to discuss. The spectrographic method in general is relatively unaffected by the things that are troublesome in other methods, the most important of which is refraction, and perhaps least important, on account of its accurate determination, the size of the Earth. This method must assume DOPPLER's principle.

The measurements of the two series of plates taken at the last two elongations of *Venus* showed greater discrepancies than had been expected, and the mean of the two sets differed by 0.4^{km}, so an investigation of the cause for the difference was undertaken. It came out that sky-plates taken with the instrument in the same adjustment as was used for the later series differed from the computed values by the same amount as did the Venus-plates, leading to the conclusion that slight differences in the closure of the slit, or a dust grain, may affect the velocity of a plate by interfering with the symmetry of the

comparison-lines. The value obtained for the probable error of a single Venus-plate was $\pm 0.23^{km}$, of a single sky-plate $\pm 0.18^{km}$. From this we may infer that an instrument five times as powerful would give a result five times as accurate, or a p. e. of $\pm 0.04^{km}$ for a single plate, that is $\pm 0.006^{km}$ for the mean of fifty plates. This would be about the accuracy of an *Eros* determination of the parallax $\pm 0''.004$. A grating ruled 15,000 lines to the inch would give, in the third order, the same angular dispersion as the Mills at λ 4500; 20,000 lines to the inch, third order, or 15,000 lines, fourth order, would give a third more angular dispersion than the Mills, and the resolving power in either case would be over five times that of the Mills if it were a 6-inch grating. The focal length of the Mills camera would have to be multiplied by 3.5 to give sufficient linear dispersion, but it might not pay to increase the collimator focal length in the same ratio, owing to the limited size of gratings that can be ruled. Supposing that this spectrograph and the horizontal telescope necessary to concentrate the light on the slit effectively utilized twenty per cent as much light as the Mills attached to the Lick 36-inch telescope. Throughout the rest of the optical train, the grating would have to throw eight per cent of the incident light into one of the higher orders on one side—not an entirely unknown occurrence—in order to photograph the spectrum of *Venus* in thirty minutes. The Mills gives a dense negative in two minutes. If at one of the next two elongations of *Venus* which are favorable for northern observations a series of plates of the planet and the sky were taken with such a spectrograph as we have considered, and each Venus plate measured with reference to a separate sky-plate taken the same day, the accuracy of measurement ought to be five times as great as we get with the Mills, and the probable error of a single plate should be as low as $\pm 0.04^{km}$ or $\pm 0.05^{km}$. While we may never get so accurate a value of the parallax by spectrographic methods as by the direct and indirect methods now in use, there is little doubt that a value could be obtained such that its probable error would be much less than the amount by which the values determined directly and indirectly differ, and the result might help to throw light on the cause of the present difference.

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA. K. BURNS.

A Spectrographic Study of the Fourth-Class Variable Stars *Y* Ophiuchi and *T* Vulpeculæ.[1]

Introduction.

On account of the extremely small displacements of spectrum lines, due to the radial velocities of the stars, it is desirable to use spectrographs of as high dispersion as possible. The amount of star-light available is the principal factor in determining the upper limit of the dispersion. At present, determinations of the radial velocities of stars are made most extensively with three-prism instruments. These can be made to yield velocities reliable within a few tenths of a kilometer. The practicable limit of such an instrument, attached to the largest existing telescopes, is about the sixth photographic magnitude, which requires an exposure of approximately two and a half hours. There is urgent need for a knowledge of the radial velocities of much fainter stars. Data for the solution of important astronomical problems by non-spectroscopic methods have been obtained from a large number of stars, some of which are as faint as the twelfth visual magnitude, whereas radial velocities have really been limited to the sixth photographic magnitude. The one-prism spectrograph of the Lick Observatory was employed by Dr. R. H. Curtiss in a study of the variable star *W Sagittarii*,[2] which varies between 5.5 and 6.5 photographic magnitudes. His work showed that good velocity determinations with the one-prism instrument could be obtained, at least when the exposures were comparatively short. His average exposure was about thirty minutes. It was definitely an object of the present investigation to test the efficiency of this spectrograph for much fainter stars, requiring long exposures. The average exposures for the two variable stars selected (*T Vulpeculæ* and *Y Ophiuchi*) were 75^m and 180^m, respectively. The latter star, of about the eighth photographic magnitude at minimum, may be considered the practicable limit for this instrument, attached to the 36-inch refractor. In the case of a star whose light is concentrated in a few spectrum-lines or bands, it is of course possible to go

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[1] Thesis in partial fulfilment of requirements for the degree of doctor of philosophy in the University of California. A more complete account is published in *Lick Observatory Bulletin*, No. 118, and in the *Astrophysical Journal*, Vol. XXV, 330, 1907.

[2] *L. O. Bulletin*, No. 3, 19, 1904; and *Astrophysical Journal*, Vol. XX, 149, 1904.

several magnitudes lower. For example, the spectrum of *Nova Aquilæ* No. 2 was successfully photographed when the star was of the eleventh visual magnitude.

The dispersion of the one-prism spectrograph is one fifth that of the three-prism Mills spectrograph. The average radial velocity of the brighter stars is about $\pm$ 20^{km} per second. The equivalent displacement with the one-prism instrument, for the Hγ region, is 0.005^{mm}. A radial velocity of 2^{km} would produce a shift of 0.00002 inch (0.0005^{mm}). If the average radial velocity for the fainter stars is about the same as for the brighter, then these small displacements are the quantities to be measured on the plates taken with the one-prism spectrograph. The results obtained are considered highly satisfactory. In the case of *Y Ophiuchi*, with an average exposure of three hours, the double amplitude of the velocity-curve is only 17^{km}. On the Mills spectrograms the same linear displacements would give a curve of 3½^{km} double amplitude.

In addition to testing the possibility of extending the usefulness of the one-prism instrument for radial velocity work, it was thought that a contribution might be made toward the discovery of the causes of some of the peculiarities that are observed in short-period variable stars of the δ *Cephei* or η *Aquilæ* type. Some of the more important points to be considered in this connection are: The peculiarities of, and the relation between, the light- and velocity-curves, peculiarities of the spectrum, changes in the character of the spectrum during the period of variability, and the behavior of the individual spectrum-lines.

A Peculiarity of the Spectra.

In the variable stars of the δ *Cephei* type there is a greater richness of photographic radiation relatively to visual radiation at light-maximum than at light-minimum.[1] During the light-period the point of maximum energy on the energy-curve shifts along the spectrum, moving toward the shorter wave-lengths as the star approaches light-maximum, and back again toward the longer wave-lengths as light-minimum is approached. This fact is to a certain extent masked upon the spectrograms by

[1] The observations by WILKENS confirm this point. For five stars he finds the photographic range of brightness to be about one half greater than the visual range. —*Astronomische Nachrichten*, Vol. CLXXII, 305, 1906.

instrumental and atmospheric causes, but in a long series it can readily be verified.

The Individual Spectrum-Lines.

A study was also made of the individual spectrum-lines (blends) to determine whether any of them were shifted regularly during the light-period of the variable. For this purpose thirty-nine lines were selected, and for each line the residuals (O–C)—i. e. the velocity given by the line minus the mean for all the lines measured on that plate—were formed and plotted from the measures of thirty-four spectrograms of *Y Ophiuchi* arranged according to phase in the light-period. The same was done for thirty-five spectrograms of *T Vulpeculæ*. No definite trace of a shift of any of the lines was found which is progressive with the phase of the star in its light-period.

The Variable Star Y Ophiuchi.

Forty-four spectrograms of this variable were obtained. My measures of the first eight spectrograms showed a variable radial velocity, the total range of variation being, however, small.[1] The solution of the orbit by the method of LEHMANN-FILHÉS gave the following elliptic elements:—

$$U = 17.1207 \text{ (light-period)},$$
$$\mu = 21^\circ.026,$$
$$T = 2.6 \text{ days after light-maximum},$$
$$\omega = 209^\circ.2,$$
$$K = 8.5^{\text{km}} \text{ (single amplitude)},$$
$$e = 0.10,$$
$$V = -5.0^{\text{km}} \text{ (velocity of system)},$$
$$a \sin i = 1{,}999{,}000^{\text{km}}.$$

There is some indication of the presence of a secondary curve, with a period equal to half the light-period and a double amplitude of 2.5^{km}, superimposed upon the elliptic curve given above. This irregularity is such an extremely small quantity for the dispersion employed that we cannot place entire confidence in its reality. It would be equivalent to obtaining a secondary curve of 0.5^{km} double amplitude with the three-prism Mills spectrograph. Attention is called to the fact that the light-curve shows a similar irregularity.

[1] *Publications A. S. P.*, Vol. XVIII, 66, 1906.

More prominent irregularities in velocity-curves have been observed by CAMPBELL[1] in *ζ Geminorum,* and by R. H. CURTISS in *W Sagittarii* (*l. c.*). The cause of these secondary curves is still an unsettled question. Various explanations have been offered, such as the presence of a third body; the rotation of the brighter component; a resisting medium; or the effects of tidal forces, which must necessarily be large in such close binaries. Dr. ALEXANDER W. ROBERTS has shown[2] that considerable deviations of the principal bodies from the spherical form, in the case where the size of the stars is distinctly comparable to the size of their orbits, would give rise to a secondary period in the velocity-curve equal to half the primary period. This is a very interesting and suggestive explanation, though probably not a complete one. In *W Sagittarii* the secondary period is without doubt half that of the primary, whereas in the case of *ζ Geminorum* a secondary period, equal to one third that of the primary, satisfies the observed curve better than one of half the primary period. In a complete explanation probably a number of factors must be taken into account, and in the different individual cases one or the other of these factors may become the predominant one, and thus produce differences in the period of the secondary or in other peculiarities of this class of variables. In the course of a few years, as studies of several other variables of this and related classes will become available, we may hope to be able to speak more authoritatively in regard to the characteristics that are common to all as well as the points of difference. In individual cases we may be able to pick out the predominant influences that are at work.

The Variable Star T Vulpeculæ.

The variable brightness of *T Vulpeculæ* was discovered by SAWYER in 1885. The binary character of the star was announced by FROST in 1904. Three series of spectrograms, in three successive years, were obtained and each series is satisfied by the same velocity-curve. There is thus no appreciable rotation of the line of apsides nor rapid change of any of the other elements. The solution of the orbit was made by the method of LEHMANN-FILHÉS. After several trials of various

[1] *Astrophysical Journal*, Vol. XIII, 90, 1901.
[2] *Monthly Notices R. A. S.*, Vol. LXVI, 329, 1906.

ellipses with different values of the elements, the velocity-curve computed with the elements given below was found to reproduce the observed velocity-curve well within the error of construction of the latter. A least-square solution was therefore considered entirely unnecessary. The following are the adopted elements:—

$$U = 4^{d}.43578 \text{ (light-period)},$$
$$\mu = 81^{\circ}.1583,$$
$$T = 3^{d}.76 \text{ after light-maximum},$$
$$\omega = 111^{\circ},$$
$$K = 17.6^{km} \text{ (single amplitude)},$$
$$e = 0.43,$$
$$V = -1.3^{km} \text{ (velocity of system)},$$
$$a \sin i = 969,180^{km}.$$

In neither of these two stars could the variability be due to an eclipse, for in that case maximum and minimum brightness would occur near the points where the velocity equals the velocity of the system.

Perhaps the most important result of this investigation is the conclusive evidence of a much closer relationship between the light- and velocity-curves than has heretofore been believed to

Star.	Period.	Time Interval between Maximum Brightness and Greatest Negative Velocity.	Observer.	Reference.
	Days.	Days.		
ζ Geminorum ..	10.15	+ 0.2	W. W. CAMPBELL at L. O.	*Astrophysical Journal*, XIII, 90, 1901
η Aquilæ	7.18	+ 0.2	W. H. WRIGHT at L. O.	*Ibid.*, IX, 59, 1899
δ Cephei	5.37	— 0.2 ±	A. BELOPOLSKY at Pulkowa.	*Ibid.*, I, 160, 1895
W Sagittarii ..	7.60	+ 0.1	R. H. CURTISS at L. O.	*Ibid.*, XXII, 274, 1905
T Vulpeculæ ..	4.44	— 0.3	S. ALBRECHT at L. O.	This article
Y Ophiuchi ...	17.12	+ 1.3 ±	S. ALBRECHT at L. O.	This article
U Aquilæ	7.02	+ 0.5 ±	S. ALBRECHT at L. O.	Not published
X Sagittarii ...	7.01	+ 0.3 ±	J. H. MOORE at L. O.	Not published
S Sagittæ	8.38	0. ±	R. H. CURTISS at L. O.	*L. O. Bulletin* 62
SU Cygni	3.85	+ 0.5 ±	J. D. MADDRILL at L. O.	*Pub. A. S. P.*, XVIII, 252, 1906

exist. If the light is sent out equally in all directions from the variable star, the positions of light- and velocity-maxima and minima should bear no special relation to each other, for the brightness would be independent of the direction from which the star is observed, while the radial velocity at any instant is dependent upon the direction of the observer. For different stars

we should, therefore, expect the two curves to be shifted by different amounts relatively to each other around the period. For some stars greatest positive velocity would come at light-maximum, in others at light-minimum, and in most cases at other points along the light-curve. The table of the ten variables of this class for which both light- and velocity-curves are available shows that light-maximum and most rapid approach always occur together. Likewise, there is a time-correspondence between minimum brightness and greatest velocity of recession. We should therefore also expect that when irregularities[1] exist in both light- and velocity-curves, they will correspond to each other in position and perhaps also in shape. Of the ten stars in the above list only two have thus far shown marked irregularities in both light- and velocity- curves. They are *W Sagittarii*[2] and *Y Ophiuchi;* and for these the irregularities in the two curves correspond very closely.

This establishes the fact that in the variable stars of the *δ Cephei* type the light- and velocity-variations are very intimately connected; that both are due to the same causes; and that, if the velocity-variation is dependent upon the direction of the observer, so also must the observed light-variations be dependent upon the same factor.

At present the best theory for this class of variables seems to be that they are binaries, in which one of the component stars is considerably brighter than the other. The observed velocity-variation follows mainly as a direct consequence of the orbital motion of the brighter component. The light-variation seems to be caused in some way (other than eclipse) by the influence of the darker companion. The very close correspondence between the light- and velocity-curves in regard to period and shape, and the agreement of the times of occurrence of maximum brightness with greatest velocity of approach and minimum brightness with greatest velocity of recession, would indicate that the light-variation is not so much dependent upon the position of the brighter component of the system in its orbit as upon the direction from which the star is observed. This would ascribe less direct influence to the darker com-

[1] All the irregularities observed in the brightness- and velocity-curves of the stars contained in the table fall between light-maximum and light-minimum, except in the case of *ζ Geminorum*.

[2] *Astrophysical Journal*, Vol. XXII, 274, 1905.

panion in the matter of liberating an unusual amount of energy in a certain part of the orbit, most likely a small fraction of the period after periastron passage. Dr. CAMPBELL has called my attention to the fact that the *Algol* variables, which are binaries of even shorter average period than the δ *Cephei* variables, show no evidence of light-variation other than that caused by eclipse, and that the apparent failure of two *Algol* components to disturb each other should make us careful in ascribing the total observed effects in δ *Cephei* variables to the mutual disturbing powers of the components. Most of the eclipse variables have earlier-type spectra (*B, A,* and *F*) than the variables of Class IV. It is not impossible that in close binary pairs having the simpler types of spectra (*Algol* variables) the mutual disturbances are less effective in producing brightness-variations than in close pairs having older types of spectra (δ *Cephei* variables).

S. ALBRECHT.

ON THE DISTORTIONS OF PHOTOGRAPHIC FILMS ON GLASS.[1]

Introduction.

In various lines of astronomical research depending upon photographic plates, discrepancies of a considerable magnitude occasionally appeared, which seemed attributable to no definite cause. On the star-photographs taken with the Crossley reflector these occasional discrepancies, which seemed to be more or less accidental, usually amounted to a few tenths of a second of arc, and very rarely to as much as a second of arc, which is equivalent to a linear distance of about 0.001 inch (0.02^{mm}). Even though discrepancies are the exception rather than the rule, and discrepancies of the magnitude referred to above are extremely rare, nevertheless they cause considerable annoyance when extreme accuracy is desired, for the error of measurement need not much exceed 0.001^{mm}. It seems highly desirable definitely to locate, if possible, the cause of the difficulty. In the case of the Crossley star-photographs it seemed for a time as though the cause must be sought for in the large mirror of the telescope. Another alternative was the study of the photographic film itself. Accordingly, in the winter of 1904,

[1] Thesis in partial fulfilment of the requirements for the degree of doctor of philosophy in the University of California. A more complete account is published in *L. O. Bulletin*, No. 118, and in the *Astrophysical Journal*, Vol. XXV, 349, 1907.

at the suggestion of Director CAMPBELL and Dr. PERRINE, the writer undertook an investigation of the distortions of the gelatine film.

The more important features of the plan upon which my work was begun were investigations of the effects of (*a*) the position of the plate during the processes of washing and drying, (*b*) the rate of drying, (*c*) abrupt changes in the rate of drying during the process, (*d*) change in the position of the plate while drying, (*e*) hardener. Emulsions on plate-glass were also tried. JEWELL's developer was used, and the plates were 3¼ x 4¼ inches (83 x 108^{mm}) in size, the same as are used with the Crossley reflector.

Summary of Results.

1. For the size of the plates used (3¼ x 4¼ inches) it was found to be entirely indifferent whether the plate be vertical or horizontal during development, fixing, washing, and drying.

2. Within the range of the observations, hardener, the rate of drying, and changes in the rate of drying and in the position of the plate during the process of drying introduced no general distortions of the gelatine film.

3. Local distortions were found on artificial-star plates and on spectrograms. These distortions were confined in each case to an area equal to a small fraction of a square millimeter. The largest lateral displacement found at any point in the distorted area was 0.02^{mm}, while the great majority were less than one fourth of this amount. Some of these displacements are several times as large as the errors of measurement, and their possible effects must be taken into account where great accuracy is desired.

4. These distortions seem to be principally of two different kinds: one was due to an actual movement of a minute portion of the film, the other was an apparent shift of the image due to the peculiar arrangement of the silver grains or to local differences in the sensitiveness of the film.

5. The results obtained from one plate-glass plate showed no advantages of the plate-glass over the ordinary commercial plates in the matter of distortions of the film.

6. If the results obtained in this investigation for small plates be found to apply with equal force to larger plates, it will follow that the assumption which is the basis for the use of

the reseau is not well founded. The assumptions involved, briefly stated, are as follows: First, general distortions exist; second, they differ in different parts of the plate; third, they may be assumed to be linear within the squares of the reseau (i. e. over a stretch of 5^{mm} or more). The supposed advantages of the reseau over the method of referring all the measures to a common center rest entirely upon the validity of these three assumptions. If the reseau can be dispensed with there will be a saving of the labor involved in making the large number of settings on the reseau-lines and in the reductions of the measurements.

S. ALBRECHT.

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,
May, 1907.

NEW DOUBLE-STAR DISCOVERIES.

Since the publication of the list of two hundred and fifty new double stars in *Lick Observatory Bulletin*, No. 109, more than one hundred additional pairs have been discovered with the 36-inch and 12-inch telescopes of this observatory. Included in this number are the following, which seem worthy of special note:—

29 *Hydræ* = β 590. The 36-inch shows that the principal star is a close double. My measures are:—

1907.21	182°.8	0″.17	7.2– 7.2	2^n	*A* and *B*.
1907.21	175 .4	10 .79	6.7–12.5	2	*A B* and *C* = β 590.

According to BURNHAM, the principal star has an annual proper motion of 0″.068 in 268°.3. It is clear that this is common to both components, for otherwise the close pair would have been detected by BURNHAM when he discovered the faint star. Measures of *C* show no relative change, hence this star, too, belongs to the system.

B. D. + 46°.2054 = Es. 75. The southern star of ESPIN'S pair is a neat double. My measures give:—

1907.40	275°.7	0″.63	9.7–9.8	3^n	*A* and *B*.
1907.39	35 .6	4 .39	9.2–9.3	2	*A B* and *C* = ESPIN 75.

In *Astronomische Nachrichten*, No. 3784, ESPIN gives the position for 1880 as $12^h\ 15^m.9$; + 46° 29′, and this is copied by BURNHAM in his general catalogue. It should be $15^h\ 15^m.9$; + 46° 29′.

53 (μ^2) *Boötis*. The 36-inch telescope shows that this naked-eye star is *an exceedingly* close double. Measures on

two nights give the distance as only 0″.08 in position-angle 237°.0. In the Harvard photometry the magnitude is given as 4.93, and the two components appear to be of equal brightness. Meridian observations show that the star has a small but well-determined proper motion, and it is therefore obvious that the two components form a physical system. It may be added that 52 and 53 *Boötis* form a close pair when viewed without a telescope.

B. D. + 15°.4181. This 6.5-magnitude star is another example of the close pairs detected with the 36-inch telescope. Measures on one night give:—

1907.519	324°.3	0″.16	7.0–7.0

It is certain to prove a binary system, and it is a member of the class to which most of the rapid binary stars belong. According to AUWERS, the meridian observations give it an annual proper motion of 0″.068 in 297°.4.

B. D. + 52°.2963 = β 370. The 36-inch shows two companions which are too faint to be seen with any telescope previously used to measure BURNHAM'S pair. My measures are:—

1907.44	326°.5	3″.30	8.0– 9.0	2n	*A* and *B* = β 370.
1907.44	349 .0	2 .20	9.0–14.5	2	*B* and *C*.
1907.44	239 .5	7 .30	9.0–14.5	2	*B* and *D*.

July 22, 1907.

R. G. AITKEN.

GENERAL NOTES.

Astronomy in Canada.—During recent years the claims of astronomy as a subject for study and research have received marked recognition in Canada. The most striking evidence of this is seen in the fine observatory erected by the federal government on the outskirts of the capital, Ottawa. It was begun in 1902, and occupied in April 1905. The building is a handsome and substantial one, constructed of gray sandstone with brown sandstone trimmings, and finished within in polished oak. The equipment is of the highest grade. The chief instrument is a 15-inch equatorial by BRASHEAR and WARNER and SWASEY, and among its accessories are a position-micrometer, a registering wedge-photometer, a solar camera, a stellar camera of 8-inch aperture, and a universal spectroscope by BRASHEAR. A spectrograph for determining radial velocities has been made at the observatory workshop, and performs admirably. In addition, there is a portable Cooke-Taylor equatorial of 4½-inch aperture; a coelostat with 20-inch mirror; a concave-grating spectroscope of 10-foot radius of curvature; a Fuess heliostat; a 3-inch Cooke transit instrument with traveling-wire micrometer eye-piece; a Bosch seismograph; and a 6-inch meridian-circle is being installed.

The observatory is not connected with any educational institution, but is the official home for astronomical work of the Canadian federal government, the director being Dr. W. F. KING, the Chief Astronomer of the Dominion.

At present a geodetic survey of the country is under way, being carried on chiefly by Messrs. KING, BIGGER, and KLOTZ, while there is much activity in astrophysical research, this being in charge of Mr. J. S. PLASKETT.

At the University of Toronto there have been improvements in the teaching of astronomy, and better facilities for practical instruction and research are under consideration. At present the students in engineering are fairly equipped for geodetic work, while the students in arts have the privilege of using the 6-inch Cooke equatorial and the 3-inch transit instrument belonging to the Dominion Meteorological Observatory, besides receiving some instruction in astrophysics. It is intended to

erect a new observatory in the immediate future. The plans are not yet drawn, but as the new Board of Governors, created last year, are desirous of seeing the university rank with the best in America, it is expected that the equipment will be adequate both for ordinary instruction and research.

Another indication of progress is seen in the success of the Royal Astronomical Society of Canada. The society was founded in 1890 (under another name), and all through its life has received enthusiastic support. The headquarters are in Toronto, but during the last year sections of the society were organized in Ottawa and Peterborough, and several more are under way. In this manner it is hoped to excite interest in the subject in various localities. For some years the Ontario government has given an annual grant, which allowed the issuance of an annual volume of *Transactions*; but a year ago the federal government also gave a grant, and by its assistance a *Handbook* for observers was published, and a bi-monthly *Journal* was also inaugurated. It is hoped to secure further support and make the *Journal* a monthly publication, and it is the aim of those in charge of it to make it a credit to Canadian science. The membership of the society is about four hundred.

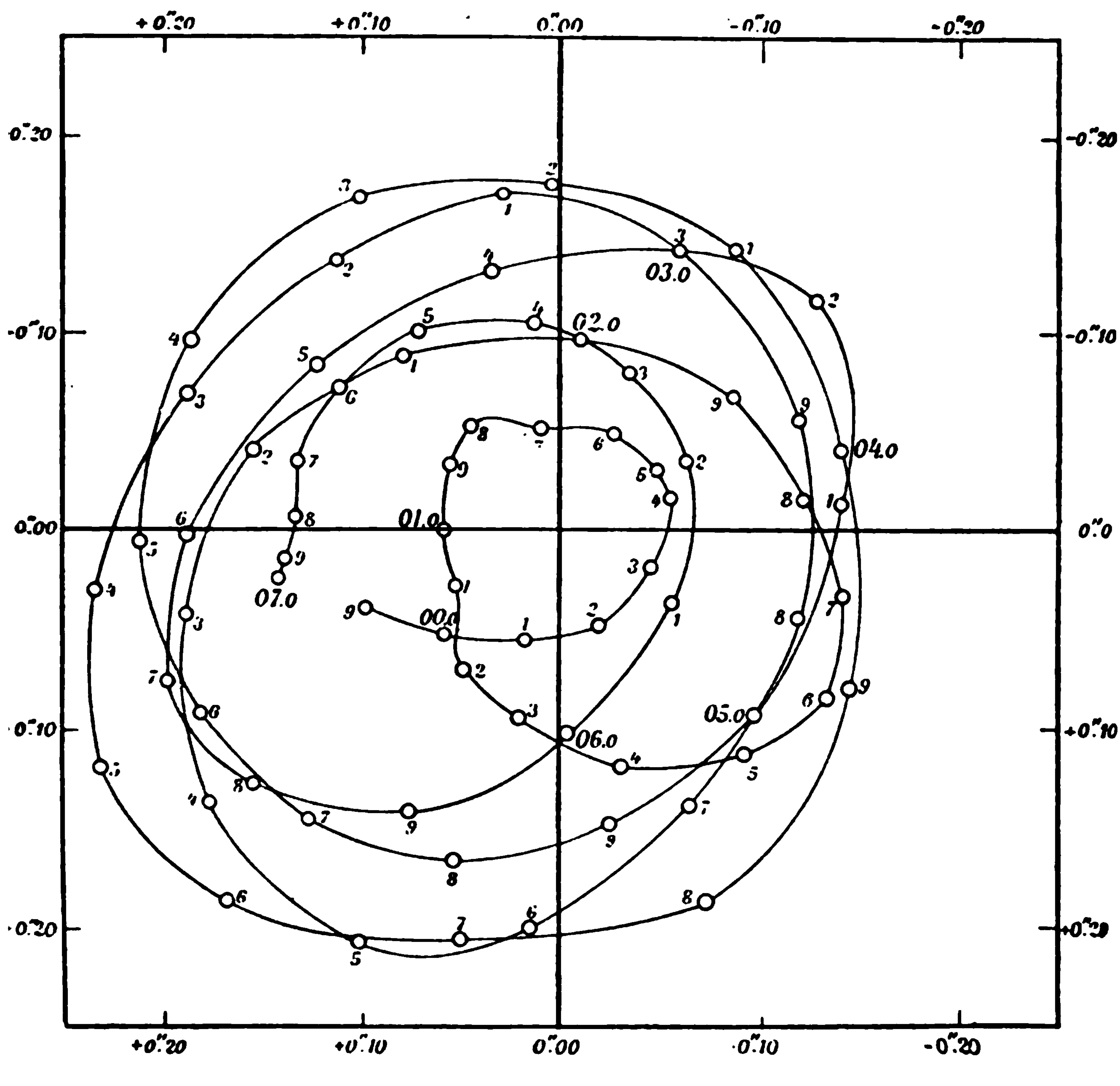
C. A. CHANT.

Variation of Latitude.—From the annual report of the Central Bureau of the International Geodetic Association it appears that the number of latitude determinations made at the various stations established for the purpose of determining the variation of latitude gives a total for 1906 of 12,153, distributed as indicated in the first column of the tabulation given below. The total number of observations made from the time the stations were established, fall of 1899, to the beginning of 1907 is 87,264, distributed as indicated in the second column of the table.

	1906.	Total.
At Mizusawa	1,685	11,718
Tschardjui	1,876	12,920
Carloforte	2,879	22,530
Gaithersburg	1,954	12,741
Cincinnati	1,409	10,974
Ukiah	2,350	16,381

It is learned from the same source that observations were begun during 1906 at the two stations on the southern parallel; on January 6th at Bayswater (West Australia), and on May 5th at Oncativo (Argentine Republic). Good progress was made at both stations, observations being obtained at a rate of over two thousand a year. The observatories at Leiden, Pulkowa, and Tokyo also co-operate with the International Geodetic Association and make continuous observations for latitude. Since the beginning of 1907 observations are being made also by Mr. INNES, at the observatory in Johannesburg, South Africa.

Since the appearance of the last number of these *Publications* provisional results for the latitude work on the northern parallel in 1906 have been published by Professor ALBRECHT, in the *Astronomische Nachrichten,* No. 4,187. The amplitude of



the polar motion continued to decrease during the year, as may be seen by reference to the accompanying illustration, taken from the number of the *Nachrichten* mentioned above, and showing the motion of the Earth's north pole from 1899.9 to 1907.0.

It will be seen from the figure that the position of the pole at the beginning of 1907 is very close to the position first determined when the observations were begun, in the fall of 1899. With reference to the motion of the pole, Professor ALBRECHT says: "Now that we have before us the results of seven years of observations, it becomes evident from them that the assumption of a yearly term and one of fourteen months' period is no longer sufficient to adequately explain the observed path of the pole." S. D. T.

Comet 1894 IV.—In *Bulletin* No. 12 of the Laws Observatory of the University of Missouri, Professor SEARES presents some of the results of his investigation of the orbit of periodic Comet 1894 IV (E. SWIFT).

All the observational data were secured during the comet's traversal of a heliocentric arc of 39° in 1894-5. It would undoubtedly have been seen again in 1901 under ordinary conditions, as account was taken[1] of the perturbations of *Jupiter, Saturn,* Earth, and *Mars* over the seven years. But at its maximum brightness, in 1901, it was fainter than when it passed beyond the power of the 36-inch Lick refractor in January, 1895,—unless some physical change had radically increased its intrinsic brightness. According to the schedule, it has just come to perihelion on another return, and should be rather brighter than at discovery in 1894. Professor SEARES has computed two ephemerides, one assuming the computed perihelion, July 9th, and the other assuming perihelion sixteen days later, throwing the comet about 10° back in its predicted orbit. The uncertainty is due to the meager observational material, and to the large perturbations by *Jupiter* in 1897, when the comet was within half an astronomical unit of the great planet for over six months. Professor SEARES has therefore neglected the comparatively slight perturbations in the interval 1900-1907, during which there was no close approach to any of the major planets.

[1] *Astron. Nach.*, No. 3656.

If the comet is not rediscovered in the next few months there is small chance of its being seen again. If it is found, Professor SEARES' elements of 1894 can be improved, and it should then be possible to demonstrate the identity or non-identity with DE VICO's comet, 1844 I. The elements of 1844 and 1894 are too uncertain for this purpose.

Professor SEARES does not comment on the converse aspect of the problem. It may be suggested that the *assumption* of identity and computation of the greater disturbances over the fifty years might have yielded elements for 1894 which would have given more accurately the perturbations since 1894. The rediscovery would be simple if the well-grounded assumption is valid. The disintegration of comets seems inevitable, and as the power of comet-seekers is exceeded, and larger apertures become necessary, the limited field greatly lessens the chance of rediscovery. It seems, therefore, that such a computation would have been worth while. It seems, too, that the magnitude of the task need not have been overwhelming. There is ample reason to hope, however, that the comet has not faded beyond the power of comet-seekers, and that the diligence of the comet hunters will be rewarded. Professor SEARES' ephemerides should be ample for their purpose.

JAMES D. MADDRILL.

Notes from Science.—Dr. J. HALM, assistant at the Royal Observatory, Edinburgh, has been appointed first assistant at the Cape Observatory, in succession to Mr. S. S. HOUGH, F. R. S., who was recently promoted to succeed Sir DAVID GILL as H. M. astronomer at the Cape.

Professor GEORGE C. COMSTOCK, director of the Washburn Observatory, University of Wisconsin, was honored with the degree of doctor of laws by the University of Illinois at its commencement on June 12th. A week later the University of Michigan conferred upon him the honorary degree of doctor of science.

Dr. ALEXANDER STEWART HERSCHEL, F. R. S., honorary professor of physics at the Durham College of Science, died on June 18th. Professor HERSCHEL died at the Observatory House, Slough, Buckinghamshire, where his father and grandfather made their great discoveries.

The death is announced of Dr. EGON RITTER VON OPPOLZER, associate professor of mathematics and astronomy at the University of Innsbruck.

The University of Manchester has conferred the doctorate of science on Dr. GEORGE E. HALE, director of the Solar Observatory of the Carnegie Institution.

Solar Observations in India.—A meeting of the Royal Society was held in Edinburgh yesterday—Professor A. CRUM BROWN, vice-president, in the chair. An address, dealing with the work at the solar observatory, Kodaikanal, South India, was given by Professor C. MICHIE SMITH, director of the Kodaikanal and Madras observatories. The observatory is situated on the Palani Hills, in the south of the Madras presidency, at a height of 7,700 feet above sea-level. Long ago it was recognized that India offered many advantages for work on the Sun, but it is only within recent years, after careful inquiries, that Kodaikanal has been selected as the site of the observatory. The hill chosen is an almost ideal site, standing in the midst of a large area of rolling downs, naturally grass-covered but recently planted with eucalyptus. The foundation-stone of the observatory was laid by Lord WENLOCK, governor of Madras, in October, 1895, but, owing to various causes, little was done to the building for nearly three years, and not until the beginning of 1899 was the work far enough advanced to enable the lecturer to take up his residence on the spot. The work consists essentially of as complete a study of the solar surface as possible. The Sun is photographed every morning when it is visible; the prominences are observed, both visually and photographically, and sun-spot spectra are studied in detail. The most interesting instrument in the observatory is the spectroheliograph, with which photographs of the Sun in monochromatic light are taken, so that the details of the distribution of the hot and cold gases may be studied all over the Sun's disk. In addition, the fullest meteorological observations are made, and there is a subsidiary base station some seven thousand feet below and about ten miles distant. Earthquakes are recorded with the Milne seismograph, and a magnetic installation under the direction of the Great Trigonometrical Survey of India is also established.—*The Scotsman.*

Royal Observatory, Greenwich.—A member of the Society has kindly sent a clipping from *The Times*, giving an account of the report of the Astronomer Royal presented to the Board of Visitors at the time of their annual visitation. After giving an account of the work accomplished with the transit instrument, the altazimuth and the reflex zenith tube, and describing the work accomplished on the nine-year catalogue, the account proceeds as follows:

"The 28-inch equatorial has been used mainly for the observation of close double stars; *κ Pegasi* has been observed on fourteen nights, the period of this star is 11.4 years, and it has now been observed through an entire revolution with the 28-inch. Altogether 129 observations have been obtained during this period, the separation never exceeding 0".3. Similarly *δ Equulei* has been observed on eighty-eight nights during its revolution of 5.7 years.

"With the 26-inch refractor thirty-seven photographs of *Neptune* and his satellite were obtained on eighteen nights. The 30-inch reflector has been used for the photography of very faint objects, the most interesting of these being *Jupiter's* sixth and seventh satellites, which were photographed on twenty-nine and seven nights respectively. As very bad weather was experienced last winter at the Lick Observatory, which devotes itself more particularly to these satellites, the Greenwich places will be of additional value. Fifty-four minor planets have been photographed, the most interesting being No. 588 *TG*, whose period is almost, if not quite, the same as that of *Jupiter*, so that there is considerable probability that it may exemplify LAGRANGE'S famous proposition, that three bodies, whatever their masses, may move permanently at the angles of an equilateral triangle. This proposition was enunciated more than a century ago, but no example of it was found till now.

"The approaching return of HALLEY'S comet is commencing to engross attention at Greenwich, which is appropriate, as Greenwich Observatory was one of the first to obtain observations of this comet at its return in 1682, and these observations were utilized by Dr. HALLEY, afterwards astronomer-royal, in the famous researches in which he established the period of this comet. As long ago as 1864 DE PONTÉCOULANT had published details of the return in 1910, from which time no one else has published anything on the matter. As there were strong reasons for suspecting that he had made a notable error in his value of the eccentricity, Mr. COWELL undertook a rediscussion, and found that, in fact, PONTÉCOULANT'S value was wrong, so that, while he made the comet's distance from the Sun at its next return sixty-four millions of miles, the true value is only fifty-five millions. There is a slight chance that the comet may be photographed at the end of this year, when its distance will be about eight astronomical units, and an accurate knowledge of its position will obviously be of great assistance in detecting such a faint object. Should the comet not be visible then it will in all probability be detected a year later, when it will be near

the orbit of *Jupiter*. The exact day of the next passage cannot yet be given; indeed, since all computers have used some approximations to simplify the work, we must be prepared for an error of a few days in any prediction.

"Photographs of the Sun were obtained at Greenwich on 210 days, and these were supplemented by others taken in India and Mauritius, so that only one day in 1906 is without a photograph. A new departure has been made in the method of publishing the solar results, which should be a great convenience to solar physicists. As soon as the series of plates is complete, rough values of their positions and definitive numbers and descriptions of the groups are now published month by month in the *Observatory*, a magazine edited by members of the staff.

"The astronomer-royal again alludes in his report to the danger caused by the electrical generating station. The committee of three appointed to inquire into the question presented a report to Parliament, in which they made several recommendations as to the manner of working the station. 'If all these are strictly carried out it may be hoped that the work of the observatory will not be seriously interfered with, though further experience when the generating station is completed and in full work may modify this view.' It is found that the vibration trouble may be overcome by using a very thin film of mercury in the trough for reflection observations, but it is feared that the vibration of the instrument, which is undoubtedly going on, may impair delicate work, such as the measurement of close double stars. The danger from smoke and heated air is more insidious, for it is not possible to prove it by immediate statistics; it will be shown only by the gradual deterioration of the observations of low north-stars.

REVIEW.

BURNHAM'S GENERAL CATALOGUE OF DOUBLE STARS.[1]

BY ERIC DOOLITTLE.

For several years all astronomers interested in double-star observation have been anxiously awaiting the appearance of this great work. It has long been known that Mr. BURNHAM had at enormous labor formed a complete record in manuscript of practically every double-star measure ever made, and that he had kept this continually posted to date by the addition of each new discovery and measure as it was published. His own account of the need he felt for such a work when he first began his long list of discoveries, and of how he proceeded to obtain it, is found in the "Introduction to the General Catalogue of 1290 Burnham Stars." When the last sentence of this account is duly weighed I think it will be admitted that there are indeed few who would have had the courage to undertake so extensive a labor, and still fewer who, having begun it, would have carried it to a successful conclusion.

"The want of a single catalogue of all double stars visible in the northern hemisphere was very manifest soon after the commencement of the observations with the 6-inch refractor. Many pairs were picked up on every good night which it was desirable to identify with as little loss of time as possible. If wanting in Struve, Herschel, and other of the old catalogues, they might still be known pairs, and it was unsafe to assume that they had not been before observed without a careful examination of minor lists, catalogues, and observations of various kinds scattered throughout a large number of volumes issued by observatories and societies, periodicals, handbooks, and monographs printed in the last hundred years. I was therefore compelled, in the interest of my own work, to bring this material together and arrange all the pairs in order of right ascension in a general catalogue. In this way I made a manuscript catalogue of every known double star within 121° of the north pole, giving the details of measures, magnitudes, star-catalogue references, etc. With this at hand, it was but a moment's work at the telescope to identify any known object, and to decide at once whether or not an object thus found was really a new pair. This catalogue subsequently passed into a second manuscript edition. This

[1] A General Catalogue of Double Stars within 121° of the North Pole, by S. W. BURNHAM. 2 vols. 4to. pp. lxiii + 1086. The Carnegie Institution of Washington.

served the purpose for a good many years, but the time came when the manuscript became too crowded by the interlineation of stars discovered by myself and other observers, and by the addition of a great number of references to measures and observations, and then I undertook the preparation of a third manuscript edition, which was arranged in the proper form for printing, with ample space for new stars and new observations, and giving a brief statement or discussion of the character of each pair of any general interest. This catalogue is substantially bound in twelve volumes. Very few will fully appreciate the enormous amount of hard work which has been necessarily expended in the preparation of such a work. Whether it will ever assume other than the present manuscript form remains to be seen. It should be remarked in this connection that, with the exception of the four years 1888-1892, all of this astronomical work, with the telescope and otherwise, has been done when eight or more hours of at least six days in the week were more or less occupied with other and very different affairs of life."

This manuscript catalogue was the only work of its kind in existence. Since its formation nearly all double-star observers have been indebted to Mr. BURNHAM for his willingness not only to compare their discoveries and measures with it, but even to copy out for them long lists of stars on which measures are needed. It has long been felt by many that in no direction could money be more profitably spent for the advancement of astronomy than in securing the publication of this catalogue. This has now been accomplished; the work appears as Publication No. 5 of the Carnegie Institution of Washington.

The great value of the catalogue lies not so much in its use to the searcher for new pairs—though to him it is almost indispensable—but more especially in its help to the measurer of known pairs. It should wonderfully increase the efficiency of all double-star work in this direction for many years to come. Without it the preparation of an observing-list has been a long and unsatisfactory undertaking. The observer began by forming a preliminary list of perhaps eight hundred or a thousand stars, which on account of their neglect or motion seemed to require remeasurement. The next step was to go over all the scattered measures in the books and journals which were accessible to him and to strike off one after another each pair which proved to have been adequately measured elsewhere. From the preliminary list he was fortunate if three hundred or four hundred stars remained to constitute his final *working list*, and unless the libraries to which he had access

were unusually complete he could not even be certain that there were not many of these on which his labor of observing was wasted. When it was a question of rejecting or observing isolated pairs met with after his observing-list was made up, and which seemed of interest for any of several reasons, the matter was still more uncertain. It would always be easier to remeasure such pairs than to hunt through all the prior records of observations, but to do this was to risk wasting a part of the limited number of clear hours available for work. Now that the catalogue is published, all of this labor requires but a few hours, and the observer can easily make certain that the stars which he selects are those most urgently in need of measurement.

The catalogue in printed form comprises two quarto volumes of more than one thousand pages, but, in spite of its size, it is a marvel of compactness. The introduction, which might easily have been expanded into a hundred pages or more, is condensed into very slightly more than eight, the index to seven thousand pairs discovered by the more prominent modern observers is reduced by an ingenious scheme of tabulation to but ten pages, and the seven tables giving the classification when possible of the more than thirteen thousand pairs, as to the character of their motion, requires but eight pages more. This difficult principle of securing the utmost conciseness has been followed throughout, yet it does not appear that a single fact of importance has been omitted.

The first volume contains descriptions of the 13,665 double stars which have so far been discovered within 121° of the north pole. Through an appendix even the most recent discoveries of HUSSEY and AITKEN are included, so that every double star whose discovery was published not later than 1906 will be found in this work. The southern limit of —31° which is adopted for the catalogue includes all of the stars which can be well observed at the northern observatories. In Mr. BURNHAM's opinion it will probably not be until the end of the present century that measures and discoveries of pairs further south will have so accumulated as to make a similar catalogue of the southern heavens desirable.

The vexed question, Which of the pairs recorded by various astronomers as double shall be included in the catalogue? is here solved by retaining all of them. Mr. BURNHAM writes on this subject:—

"The question of drawing some kind of arbitrary line between what might be presumed to be physical systems, and those which it was practically certain could not belong to that class, was considered at an early day in the preparation of this work. It was soon apparent, from a practical application of the principles which were supposed to govern a judicious separation of the material into these two classes, that it could not be successfully done. A too liberal application of the rule would reject a comparatively small number and so accomplish but little in reducing the size of the catalogue; while, on the other hand, the rigid enforcement would necessarily exclude many stars which are of some interest at least, in consequence of changes already shown from proper motion. Then again, the names of the great astronomers attached to these stars entitle them to a place in the first catalogue of double stars, independent of any consideration of the stars themselves. I have therefore included them all, and as far as possible remeasured the large number of neglected pairs of the old observers for this work."

It seems to us that this is a most fortunate decision. It is to be noticed that, with very few exceptions, it is only the bright or very close doubles which have thus far been observed, and that the orbits of such pairs only are known to us. How many faint and comparatively wide pairs there are which are true binaries we cannot conjecture. There is at least one such example (KRUEGER 60), of which the components are of the 9.0 and 12.0 magnitude and 3".5 apart, whose period will almost certainly not exceed two hundred years. If two thousand or three thousand such pairs are catalogued and a considerable number of these afterward found to be binary, this will go far toward solving the general question of the comparative masses and distances of the faint and bright stars.

Mr. BURNHAM finds that 585 pairs have a common proper motion. Many of these are faint and widely separated, and yet it is very probable that they are physically connected, the periods being reckoned in thousands of years. Perhaps the two best-known examples are μ^1 *Herculis* and 40 *Eridani*, the former being separated by 30" and the latter by 80". That these great distances could have been attained through tidal action seems hardly possible; we cannot even conjecture what the form of their relative paths is likely to be, but to secure and record at least one good measure on every such pair is a debt which the astronomers of to-day owe to posterity. Perhaps the most liberal scheme for the exclusion of double stars is that employed by INNES in his Reference Catalogue of Southern Double Stars. Yet, were this rigorously applied, not only would the distant companions of μ *Herculis*

and 40 *Eridani* be rejected as of no interest, but these two attendants, each of which is a faint binary of comparatively short period, would both be excluded also.

The first volume contains the position of each star reduced to 1880.0, and the date, position-angle, distance, and magnitudes at the time of the first measure. For fully ninety per cent the identification is given; many of those in which this is omitted are too faint to be found in any of the catalogues.

The second volume gives a sufficient number of selected measures to show the character of motion in each pair, and in addition to these the complete references in each case to every measure which has ever been made on it and to all important notes and papers relating to it. The latest values of the proper motions of the principal stars are also included. Mr. BURNHAM is decidedly of the opinion that when many good measures are available the more uncertain ones should be unhesitatingly rejected. He says on this point:—

"For obvious reasons only the best measures by the best observers are selected as a rule, and those made on a single night have been generally rejected, except when there was nothing else in point of time to take their places. It must be clear to every one that the omission of all indifferent and superfluous observations necessarily adds to the value and usefulness of this work. The author has not been handicapped or limited in any way as to space to be used; and in the citation of observations and in the comments relating thereto he has omitted nothing that in his judgment would be worth giving. It goes without saying that a large number of the published measures of double stars should be rejected in any investigation or discussion as to the relative motion of the components. There need be no difficulty or hesitation in deciding as to the proper material to be used. If all the observations—good, bad, and indifferent—are employed in the computation of an orbit, it is certain that the value of the result will be correspondingly impaired, and no method of treating the doubtful material will prevent this."

Beside this enormous labor of compilation there is a condensed but most thorough discussion of each pair in which there has been change. Hundreds of new and carefully constructed diagrams are given in this connection. Certainly no work could be more valuable or more authoritative than this. It is needless to say that Mr. BURNHAM never attempts to get out of the measures more than the material will certainly show. Even in the introduction space is spared to emphasize the inutility of attempting to compute orbits when the measures

are wholly insufficient for this purpose, and in Part II not a line is given up to speculation or to misleading computations of future motion when this must at present be very uncertain. For several of the pairs in which a whole revolution has been completed the period only is stated, and for others for which orbits have been computed it is not even asserted that the motion is orbital at all. As might be expected, Mr. BURNHAM is equally conservative in regard to the presence of dark bodies which have been supposed to disturb the motion of the bright stars. That in *ζ Herculis* is not even mentioned, while the indications of a long suspected third body in F 70 *Ophiuchi* are believed to be equally well explained by the ordinary errors of observation.

When this great mass of material is examined Mr. BURNHAM finds the following general results: There are eighty-eight pairs for which orbits have been computed, of which, however, only thirty-four can be regarded as of any value. There are ninety-four systems which are certainly binary. There are 112 pairs which are probably binary, and thirty-eight pairs in which the two stars have different proper motions, as in the well-known system 61 *Cygni*. There are 585 pairs having common proper motion and 337 in which, from meridian-circle observations, proper motion has been observed in the principal star. Thus of the entire list of 13,665 stars there are but 879 for which a physical connection can at this time be inferred.

No discussion is attempted of the distribution of these stars on the sky, nor is any attempt made to theorize on the construction and extent of the stellar universe. While the discoveries and measures are still both so incomplete, it is the belief that all such generalizations are idle and useless. Mr. BURNHAM strongly emphasizes the fact that what is wanted now for the advancement of double-star astronomy is not theories and speculations, or even extensive computations, but only careful, prolonged, and systematic observations with the telescope. It cannot be doubted that a great impetus will be given to observations in this important branch of astronomy, and that their value will be exceedingly enhanced by the publication of this monumental work.

FLOWER OBSERVATORY, UNIVERSITY OF PENNSYLVANIA.

NEW PUBLICATIONS.

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BLOCK, H. G. Tafeln zur Berechnung der Störungen einer Gruppe kleiner Planeten durch *Saturn*. Stockholm: 1907. 4to. 20 pp. Paper.

BOHLIN, KARL. Der Zweite Sternhaufen im *Hercules*, MESSIER 92. Stockholm. 1906. 4to. 36 pp. Paper.

BURNHAM, S. W. A general catalogue of double stars within 121° of the north pole. Part I, the catalogue; Part II, notes to the catalogue. Chicago: The Carnegie Institution of Washington, 1907. 4to. lv + viii + 1086 pp. Paper.

COMSTOCK, G. C. Observations of double stars. Madison: Publications of the Washburn Observatory, Vol. X, Part 3. 1907. 4to. 106 pp. Paper.

HERZ, N. Stern-Catalog für die Zone von 6° bis 10° südlichen Declination für das Aequinoctium 1890. Abth. I. Abhandlungen der Königlich Preussischen Academie der Wissenschaften, aus dem Jahre 1906. Berlin: Georg Reimer. 1906. 4to. 92 pp. Boards.

JANSSEN, J. Observation de l'éclipse totale de soleil du 30 Aout 1905 a Alcosèbre (ESPAGNE). Annales de l'observatoire d'astronomie physique de Paris. Tome troisieme, premiere partie. Paris: Gauthier Villiers. 1906. 4to. 20 pp. (plates). Paper.

KOPFF, A. Ueber die Nebel der *Nova Persei*. Publikationen der Astrophysikalischen Instituts Königstuhl-Heidelberg. Band II, No. 9. 4to. 27 pp. Paper.

OGBURN, JOHN H. Results of observations with the zenith telescope of the Sayre Astronomical Observatory, from September 11, 1904, to September 1, 1905. South Bethlehem: Lehigh University, Astronomical Papers, Vol. I, Part I. 1907. 4to. 46 pp. Paper.

SCHILLER, KARL. Photographische Helligkeiten und mittlere Oerter von 251 Sternen der Plejaden-Gruppe. Publika-

tionen der Astrophysikalischen Instituts Königstuhl-Heidelberg. Band II, No. 10. 4to. 26 pp. Paper.

SEARES, F. H. Finding ephemerides for Comet 1894 IV (E. SWIFT). Laws Observatory Bulletin, No. 12. Columbia: University of Missouri. 1907. 4to. 4 pp.

TURNER, H. H. Astrographic Catalogue 1900.0. Oxford Section, declination + 24° to + 32°. Vol. I, measures of rectangular co-ordinates and diameters of 65,750 star images on plates with centers in dec. + 31°. Vol. II, measures of the rectangular co-ordinates and diameters of 66,718 star images on plates with centers in dec. + 30°. Edinburgh. 1906. 4to. xlvii + 223 and xlii + 232 pp. Paper.

Annales de l'Observatoire Royal de Belgique. Tome IX, Fasc. II, Observations solaires effectuées a Uccle en 1904. Tome IX, Fasc. III, Observations faites a la lunette méridienne de Gambey en 1902, 1903, 1904, et 1905. Bruxelles. 1906. 4to. 108 and 313 pp. Paper.

Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Photographische Himmelskarte-Katalog, Band IV. Potsdam. 1907. 4to. xiv + 519 pp. Boards. 25m.

Solar Physics Committee. Spectroscopic comparison of metals present in certain terrestrial and celestial light sources. (With special reference to vanadium and titanium.) London: Wyman & Sons. 4to. 37 pp. Boards. 3s.

Minutes of the Meeting of the Board of Directors held at the Students' Observatory, Berkeley, on July 13, 1907, at 7:30 p. m.

President Cushing presided. A quorum was present. The minutes of the last meeting were approved.

The following new member was duly elected:—

Mrs. W. B. Cunnane........1327 De la Vina St., Santa Barbara, Cal.

The Treasurer reported that, by order of the Finance Committee, the following bonds had been bought and paid for from the savings bank deposits, viz.:

Alexander Montgomery Library Fund (from Security Savings Bank), Contra Costa Water Company $1,000 Gold Bond No. 1665..$1,035.00

(Interest January and July; principal due January 1, 1915.)

Wm. Alvord Fund (from Savings and Loan Society), Contra Costa Water Company $1,000 Gold Bond No. 1666......$1,035.00

(Interest January and July; principal due January 1, 1915.)

Several replies to the circular letter concerning the library were read. Among other contributions to the library were two of cash. It was moved, carried, and ordered that these cash contributions be received, the money thus acquired to be expended for books, to be inscribed as the gift of the donors of said cash contributions.

The following publications were ordered placed upon our exchange list:—

The *American Astronomer.*

The *Journal of the Royal Astronomical Society of Canada.*

Replies, acknowledging with thanks the receipt of the award of the Donohoe comet-medal, from Dr. August Kopff, Rev. Joel H. Metcalf, and Mr. David Ross, were read.

Professor R. G. Aitken, of the Lick Observatory, was elected Secretary at Mt. Hamilton for the unexpired term.

Upon motion it was

Resolved, That the Committee on Publication be authorized to reprint the By-Laws, the Bruce Medal Statutes, and the Donohoe Comet-Medal Statutes.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific held at the Students' Observatory, Berkeley, on July 13, 1907, at 8 p. m.

President Cushing called the meeting to order, and introduced the lecturer of the evening, Professor R. T. Crawford, of the Berkeley Astronomical Department, who read a paper on "Our Debt to Astronomy."

The Society was very fortunate in having present Professor Simon Newcomb, to whom (in 1897) the first award of its Bruce Medal was made. After the lecture by Professor Crawford, Professor Newcomb was introduced and entertained the Society with a most pleasing informal address. At the close of the meeting the members availed themselves of the privilege of meeting Professor Newcomb.

Adjourned.

OFFICERS OF THE SOCIETY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only Subsequent annual payments are due on January 1st of each succeeding calendar year This rule is necessary in order to make our bookkeeping as simple as possible Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

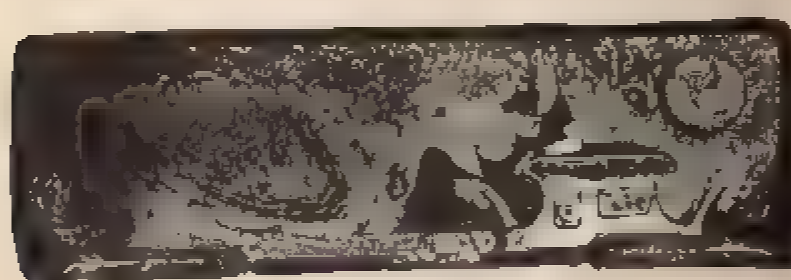
The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper 40 cents, of note paper 25 cents, a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory Berkeley, Cal, in order that arrangements may be made for transportation, lodging, etc

PUBLICATIONS ISSUED BI-MONTHLY.

(*February, April, June, August, October, December.*)



THE OBSERVATORY OF THE D. O. MILLS EXPEDITION, FROM THE NORTHEAST.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, OCTOBER 10, 1907. No. 116.

RECENT CHANGES AT THE OBSERVATORY OF THE D. O. MILLS EXPEDITION.

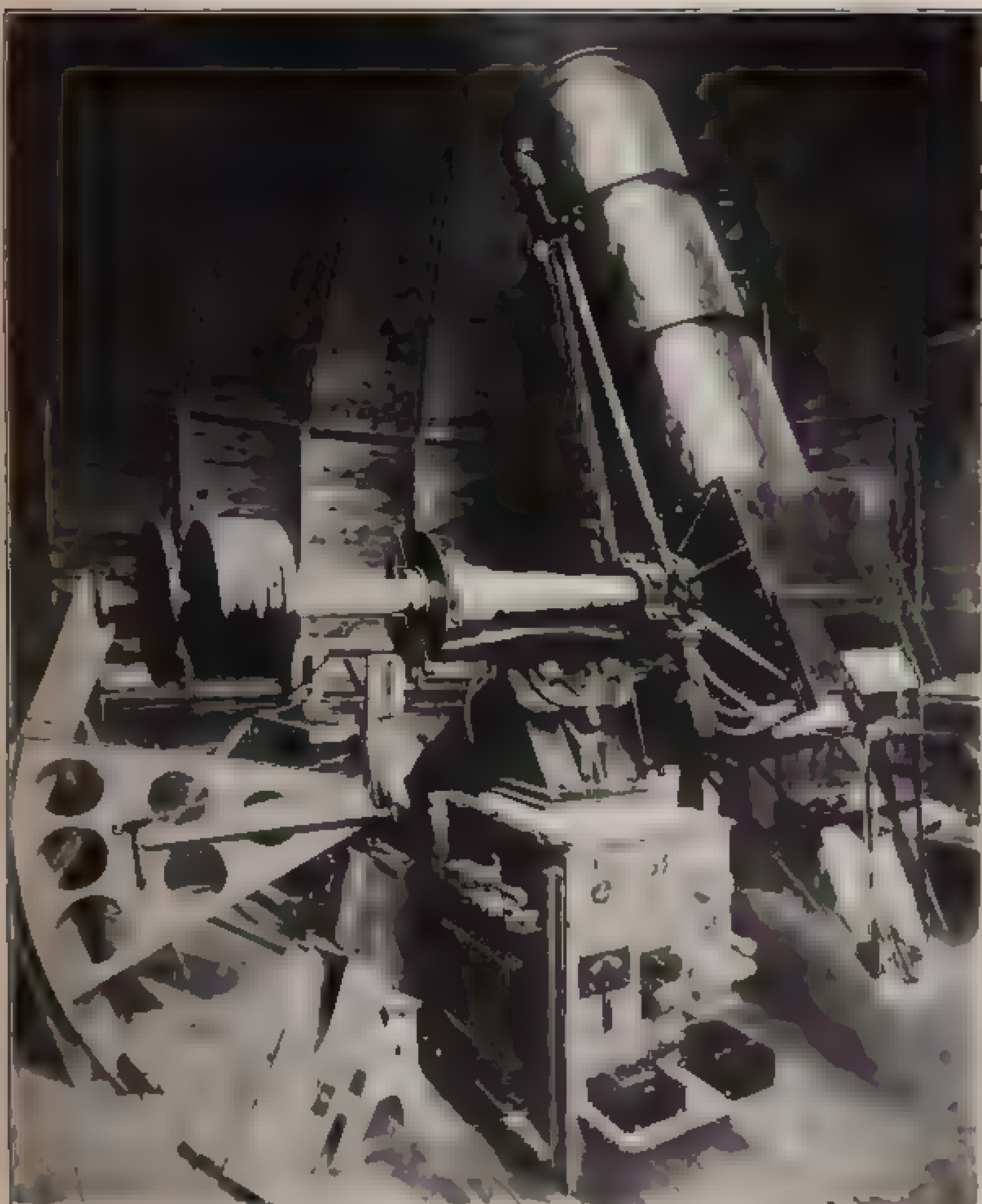
By HEBER D. CURTIS.

When Mr. MILLS provided for a continuation of the work of the D. O. Mills Expedition to the Southern Hemisphere for five years a number of improvements in, and additions to, the equipment were decided upon by Director CAMPBELL, many of which had been suggested as desirable by the experience of Professor W. H. WRIGHT and Dr. H. K. PALMER during the course of their two-year period of work in Chile. It is the purpose of this paper to describe a number of the changes in the equipment which have been made since March, 1906, the date when Professor WRIGHT returned to the United States, and the writer assumed charge of the station. Many of the minor improvements are not of such magnitude in themselves as to warrant extended notice; but if one takes into account the difficulty of accomplishment of all such alterations and additions on a hilltop not too easy of access, in a distant country, and without skilled labor, it can easily be realized that they have cost considerable effort. Mr. GEORGE F. PADDOCK, formerly Fellow at the Leander McCormick Observatory of the University of Virginia, arrived in Santiago on August 2, 1906, and has taken an active part in the installation of all improvements made since that time.

A small building, about fourteen by seventeen feet, was first built, about thirty feet to the south of the observatory dome. It contains a workshop and two small sleeping-rooms for the observers. The observatory is located 860 feet above the city and about one mile distant from the homes of the observers. This daily or nightly climb is a matter of much less bodily strain than would be thought,—after one is well hardened to it,—but there is no change which has contributed more to

the comfort of the observers than the ability to be able to "turn in" immediately after a night's work. In the workshop have been placed a 12-inch Star engine-lathe of the new heavy model made by this company, a grinder-head, a work-bench, and an extensive collection of small tools, as well as a refrigerating machine, to which reference will be made later. The machinery is driven by a one-horsepower electric motor fastened near the ceiling. The electric line from the city to the observatory was in part rebuilt and extended to connect with the circuit of the city's lighting system, and wires were also strung for telephone communication between the observatory and the writer's home at the foot of the hill.

Professor WRIGHT had found the motion of the 37-inch reflector in declination a very difficult one. The axis was of steel, finely ground at the bearing surfaces, and running in babbitt, but such was the weight of the moving parts (about two tons) that much effort was necessary to set the telescope moving in this component. The force required to start the motion averaged fifty to one hundred pounds on the end of a 6.1-foot lever, depending upon the hour-angle of the telescope. After consultation with the makers of the mounting, designs were drawn for roller bearings in each of the declination pillow-blocks, and a ball thrust bearing at the block farthest from the telescope-tube, lack of space preventing its use at the bearing nearest the tube. The new bearings are of the frictionless type manufactured by the Anti-Friction Roller Bearing Company, of Los Angeles. As this company did not have the facilities for making such large bearings as were required in this case, free use of their patent was courteously granted by them to the makers of the mounting, the Fulton Engine Works, of Los Angeles, for the construction of the roller bearings for the Mills reflector. The system for each bearing consists of tool-steel carrying-rolls three fourths of an inch in diameter, with an equal number of alternating smaller rolls, whose only function is to obviate the sliding friction between the larger carrying-rolls. There being nothing but rolling contacts, no lubricant is necessary. Steel rings one fourth of an inch square, fitting into grooves at each end of the rolls, are screwed to the axis, and, with similar holding rings outside the roller group fitting in the same grooves, serve not only to prevent end-motion in the



THE MILLS TELESCOPE, WITH THE THREE-PRISM SPECTROGRAPH

rolls, but to keep the smaller intermediate rolls in their correct positions. The rolls are eight inches long on the inboard, and five and a half inches on the outboard bearing. For the thrust a strong tool-steel sleeve was made to fit over the declination axis and a tool-steel bearing-ring provided to fit into a shallow recess in the outboard bearing. Between the two steel surfaces there moves freely a bronze ring pierced with seventy-two apertures, each of which contains a half-inch steel ball. The actual work of boring out the heavy bearing-blocks from six and a half to eight inches diameter and recessing the outer block for the thrust-ring was done on the observatory's lathe. The results have proved very satisfactory, the ease of motion being remarkable. It now takes, at a distance of 6.1 feet from the center of motion, but six to nine pounds to start and maintain the motion in declination at all ordinary hour-angles, and only sixteen to nineteen pounds in the extreme case when the telescope is at six hours hour-angle directly over the polar axis. It is now quite easy to move the telescope in declination while looking through the finder with the hand on the corner of the cube only two and a half feet from the center of the declination axis produced. With a centrally hung refractor-tube of the same weight and an available leverage of fifteen to eighteen feet, the very slight effort required to move the tube might even be a disadvantage. The responsiveness of the declination slow motion has likewise greatly improved.

The Cassegrainian system of the 37-inch Mills reflector has from the beginning been subject to progressive focal changes in the first half of the night. These changes were always in the direction of increasing focal length, it being necessary gradually and continuously to increase the focal length of the telescope during the first four or five hours of the night by amounts which reach totals of fifteen to twenty-five millimeters. It was decided to try artificial cooling of the mirror, in the hope that by reducing in advance the mirror temperature to that of the night these progressive focal changes might be greatly reduced or destroyed entirely.

As a preliminary to the testing of the refrigeration the ventilation of the mirror in its cell was bettered. The great mirror has a clear aperture of 36.56 inches, is 5.5 inches thick at the center, *and is pierced by* a central hole 4.87 inches in

diameter. The cast-iron cell is about one half inch in thickness; at the center of the back is a hole 8.5 inches in diameter, which was formerly generally kept closed with a cast-iron filler disk having a two-inch aperture for the passage of the light to the spectrograph slit. Aside from this aperture, and a few small ones for the adjusting screws of the mirror supports, the only other ventilating opening in the ironwork about the mirror was a small window six inches square cut in one side of the cube just above the mirror. The mirror cover, which had formerly rested nearly in contact with the mirror, was moved fourteen inches up the cube; the cube window was enlarged to six by sixteen inches and a similar window cut on the opposite side of the cube. Six holes, each 5.2 inches in diameter, were cut in the iron back of the cell, and the use of the filler-plate discontinued. The ventilating area at the back of the mirror is thus now about one sixth of the area of the mirror.

During the past observing season record has been kept of the focal changes, and as a result of the study of these, in connection with the temperature variations, the following general conclusions have been drawn with reference to the behavior of the mirror system without artificial cooling:—

(1) The increased ventilation about the mirror has only slightly reduced the focal range in the first part of the night, the average under normal summer observing conditions being about fourteen millimeters. A position of focal equilibrium is probably reached somewhat earlier, all focal change ceasing as a rule by four hours after sunset.

(2) Silvering the back of the mirror, as recommended by Professors WADSWORTH and RITCHEY, has had no appreciable effect in reducing the focal range. Insulating the sides of the hole in the primary mirror with blanketing has also been without effect.

(3) The focus of the system after equilibrium is reached seems not to vary noticeably for different temperatures.

(4) The focal changes have their origin in the large mirror, and not in the secondary; this has been shown by tests on a number of nights by star-trails on an inclined photographic plate at the focus of the primary. These showed a progressive lengthening of the focus of the main mirror by amounts ranging from 1.2^{mm} to 2.2^{mm}. As a focal change in the

THE ONE-PRISM SPECTROGRAPH.

THE TWO-PRISM SPECTROGRAPH.

primary produces 10.1 times as much change in the focus of the entire system, these results are seen to be in good accord with the ranges secured for the system as a whole. Similar tests on two evenings exposing alternately the inner and outer portions of the primary showed that the outer ring was about 1.2^{mm} shorter focally than the inner zone, a difference which vanished in similar tests made in the morning hours.

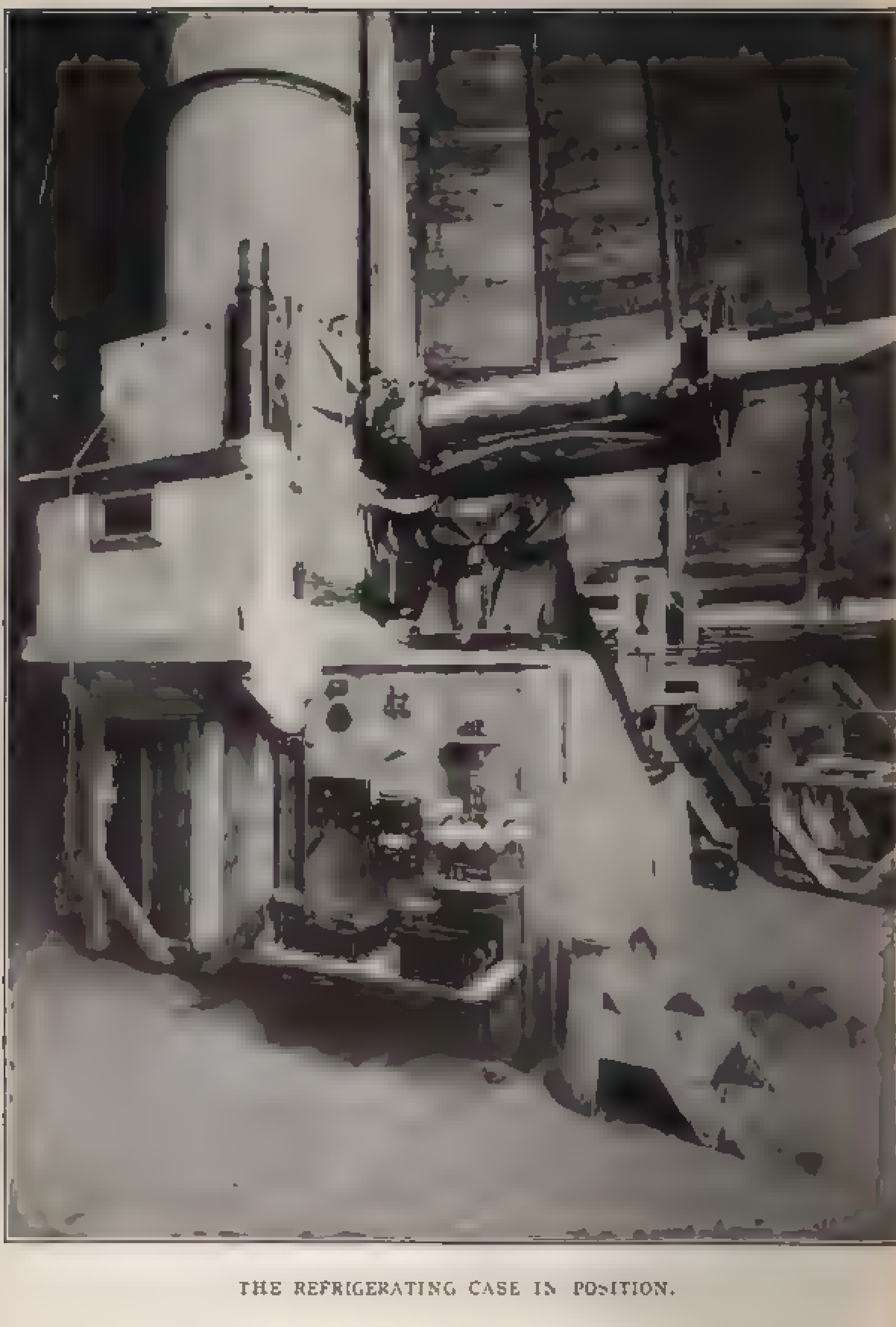
(5) The relation connecting the focal changes of the mirror with the fall in external temperature is apparently a very complex one, many factors entering in. Frequently a drop of 2° C. between the temperatures of afternoon and early evening will cause as great a focal range as a drop of 6° C. In general, the rapidity with which a temperature change takes place seems to be of greater effect than its absolute magnitude.

The system of refrigeration employed is the direct anhydrous ammonia method. The machine is the smallest of the regular commercial sizes of isolated cooling plants manufactured by the Brunswick Refrigerating Company, of Brunswick, N. J. It requires one horsepower to run it and the pump used for water circulation, and is rated by the manufacturers as having a capacity equal to that of the melting of one hundred pounds of ice per day. It is located in the shop forty-eight feet from the telescope pier, to one side of which are attached the cooling coils, three feet by two feet by six inches, of one-inch piping, and well insulated from the pier. The coils are connected with the ammonia machine by a double line of piping of one-fourth-inch bore, insulated with cork and felt. In use a removable wooden case lined with thick felt is rolled into position about the telescope; this case contains about eighty-five cubic feet and insulates from the outside air the spectrograph, mirror, and lower half of the cube. Two electric fans keep the air in the case in constant circulation. The refrigerating machine is entirely automatic in its action, and no difficulty is found in reducing the temperature within the case by 5° or 6° C. in a run of one hour and a half. After some experiments, the following procedure has been found most advantageous. Refrigeration is started about three hours before sunset and the temperature at the mirror reduced about 5° C. The case is removed from the telescope about forty minutes before sunset; at this time the outside temperature is falling rapidly, and the mirror, at least in its outer

portions, is colder than the air. Equilibrium is reached by sunset, or very shortly after, when focal tests almost invariably show the same value of the focus as that at which it had been left at the time of closing work on the night before. Focal changes are either entirely absent or small, being rarely greater than five millimeters. Sudden changes in the night temperature still produce focal changes of small amount. Fortunately the average temperature gradient during normal summer nights on Cerro San Cristobal is very regular; on quite a proportion of nights when cooling has been used there has been no focal change during the entire night.

The change in the source of electric power rendered necessary the complete rewiring of the observatory, and use was made of this opportunity to arrange all the circuits used in the spectroscopic work in a switchboard on the front of the pier. To this switchboard come, underneath the floor of the dome, a circuit from three primary cells used with the relay for the heating of the spectrograph case; a circuit from four storage-batteries, held in reserve for the spark and used at present only for small lights to illuminate the divided circles; and the 220-volt circuit, used for heating the temperature case, for lights and for the arc comparison. Arc-comparison apparatus has lately been attached to the spectrograph, though the spark is held in readiness for special work; for this latter the condenser and self-induction can be cut in or out by switches. All the electrical circuits, including the high tension for the spark, are carried up over the axes of the telescope to a line of binding-posts near the mirror cell, to which flexible cord and convenient plugs are fitted, doing away with all use of binding-posts in actual work.

A one-prism and a two-prism spectrograph have been added to the equipment. These are arranged to attach to the steel frame of the three-prism instrument by removing the box containing the three-prism train. They use the collimator, slit, comparison apparatus, and supporting truss of the three-prism instrument. The prism-boxes and camera-tubes of the new spectrographs are built up of strong brass plates, the general scheme of construction being that employed in the remounted Mills spectrograph at Lick Observatory. Tests have failed to show any flexure effects. The new camera-lenses are of the Hartmann uncemented type, consisting of



THE REFRIGERATING CASE IN POSITION.

THE REFRIGERATING MACHINE, IN THE WORKSHOP

three lenses with intervening air-spaces; the total thickness of glass traversed by the beam at the center of the lenses is 0.92 inch. The focal length of the camera for the two-prism instrument is sixteen inches, that for the one-prism eighteen inches. A special temperature-case fits either of the two new instruments. The heating arrangement is similar to that of the three-prism spectrograph, a mercurial thermostat on the steel body truss serving for all three instruments. It is Director CAMPBELL's intention that radial-velocity determinations in the southern sky shall be carried down to fainter stars with the new instruments, but owing to the long delay in gaining possession of the lenses due to the congestion of business at Valparaiso following the great earthquake, no systematic work has yet been undertaken.

Among minor additions to the equipment may be mentioned a new Toepfer measuring-engine and a Berolina calculating-machine. A photographic attachment has been fitted up to test the performance of the telescope in direct photography of clusters and nebulæ.

The resilvering of the mirror has been expedited by the building of a heavy wooden frame on wheels to withdraw the mirror and cell, and to support the mirror during the process of silvering. A convenient carriage has also been built to remove the spectrograph from the telescope. A card catalogue has been made to keep record of the results of the work; this is on the same plan as that used at Lick Observatory for the results from the northern sky.

Mr. MILLS's generosity in providing this increased equipment for the work of the next five years will add greatly to the comfort of the observers and the ease of manipulation of the instruments, besides materially enlarging the scope and quantity of the work. The present equipment, with spectrographs of one, two, and three prisms, may be considered quite complete for general work in stellar spectroscopy and determinations of stellar velocities, and will render the velocity survey of the stars of the southern heavens much more complete and comprehensive, a result of great moment in improving our knowledge of the Sun's motion through space, and of the structure of our stellar universe.

THE D. O. MILLS EXPEDITION,
Santiago, Chile, June, 1907.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon....	Nov. 5,	2^h	39^m P.M.	New Moon....	Dec. 5,	2^h	22^m A.M.
First Quarter..	" 12,	9	14 A.M.	First Quarter..	" 11,	6	16 P.M.
Full Moon.....	" 19,	4	4 P.M.	Full Moon.....	" 19,	9	55 A.M.
Last Quarter...	" 27,	8	21 P.M.	Last Quarter...	" 27,	3	10 P.M.

The Sun reaches the winter solstice and winter begins December 22d, 4 P.M., Pacific time.

Mercury is an evening star on November 1st, not very far from greatest east elongation, which it passed late in October, but eastern elongations during the last half of the year give a very poor opportunity for seeing the planet as an evening star. The interval between the setting of the Sun and of the planet is less than an hour on November 1st, and diminishes steadily until conjunction in the early morning of November 14th. At this time *Mercury* is in transit across the disk of the Sun. The principal phases of the transit in Pacific time are as follows:—

Ingress, exterior contact,	November	14,	2^h	24^m A.M.
Ingress, interior contact,	"	"	2	26 A.M.
Least distance of centers 12′ 38″	"	"	4	7 A.M.
Egress, interior contact,	"	"	5	47 A.M.
Egress, exterior contact,	"	"	5	50 A.M.

The planet will pass over the north half of the Sun. It will be seen that the transit is practically over at sunrise in the extreme western part of the country, and therefore cannot be seen there, but the latter half of the phenomenon can be seen from the central and eastern parts, the Sun rising after the beginning of transit. The next transit will occur in 1914. Transits of *Mercury* are of little scientific interest.

After November 14th *Mercury* is a morning star, and moves rapidly out toward greatest west elongation, reaching it on the morning of December 1st. It will then rise an hour and three quarters before sunrise, and the interval will not be less than an hour until some days after the middle of the month. It will therefore be an easy object to see in the twilight on

early December mornings. By the end of the month the planet will not be far from superior conjunction with the Sun.

Venus is an evening star throughout the month, and shortly after November 1st remains above the horizon long enough after sunset to be easily seen in the evening twilight. On December 1st the interval is a little more than an hour, and by the end of the month it has increased to two hours. Although it is in the part of its orbit farthest from the Earth, it will be a conspicuous object in the evening twilight.

Mars, although it has lost very much of its brilliancy, is still a conspicuous object in the southwestern sky in the evening. During November and December it changes its time of setting only twenty-four minutes, from $11^h\ 11^m$ P.M. to $10^h\ 47^m$ P.M. It moves 38° eastward and 16° northward from the middle of *Capricorn* through *Aquarius* into *Pisces*. On the morning of December 31st it is in conjunction with *Saturn*, passing 1° 50′ north of that planet. During the two months its distance from the Earth increases from 85 to 127 millions of miles, and its brightness at the end of the period is less than one half of that at the beginning, but it is in a region barren of bright stars, and there will be no difficulty in identifying it. *Saturn* is the only bright object near, and its dull yellow color distinguishes it easily from the ruddy color of *Mars*.

Jupiter rises a little before $11^h\ 30^m$ P.M. on November 1st, at $9^h\ 30^m$ P.M. on December 1st, and at about $7^h\ 20^m$ P.M. on December 31st. It is therefore getting around again into good position for evening observation. It moves about 5° eastward and 1° southward up to the end of November, and during December moves a little westward in the constellation *Cancer*.

Saturn sets somewhat earlier, but still remains in good position for evening observation. On November 1st it sets at about $2^h\ 30^m$ A.M., on December 1st at about $12^h\ 30^m$ A.M., and on December 31st at about $10^h\ 30^m$ P.M. It moves westward a little up to November 25th, and then moves eastward, making about 1° by December 31st. It is in the western part of the constellation *Pisces*. Throughout the two months the Sun and the Earth remain on opposite sides of the plane of the rings, and we look toward the dark face, but by the end of December the Earth has nearly reached the plane of the rings once more, and they are nearly edgewise toward us.

During January the Earth will cross the plane and be on the same side as the Sun. This condition of affairs will then continue for fifteen years.

Uranus is in the southwestern sky in the evening, setting a little after 8^h 30^m P.M. on November 1st, at 6^h 45^m P.M. on December 1st, and at 4^h 56^m P.M. on December 31st, only a few minutes after sunset. It will reach conjunction with the Sun early in January, 1908. Its faintness and low altitude will make it a difficult object to see at any time during the two-month period. It is still in *Sagittarius,* and moves about 3° westward. On December 11th it is in conjunction with *Venus,* the latter being 59′ to the south.

Neptune is in *Gemini,* and rises about 9 P.M. on November 1st and at about 5 P.M. on December 31st.

(FIFTY-NINTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. GIACOBINI, of Nice, France, for his discovery of an unexpected comet on March 9, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

(SIXTIETH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. MELLISH, of Madison, Wisconson, for his discovery of an unexpected comet on April 14, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

(SIXTY-FIRST) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. GIACOBINI, of Nice, France, for his discovery of an unexpected comet on June 2, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

(SIXTY-SECOND) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to ZACCHEUS DANIEL, of Princeton, New Jersey, for his discovery of an unexpected comet on June 9, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

† HERMANN CARL VOGEL. †

It is with the deepest regret that the Astronomical Society of the Pacific has learned of the death, on August 14th, of one of the world's most distinguished astronomers, Geheimer Ober-Reg. Rath Professor Doctor HERMANN CARL VOGEL, Director des Astrophysikalischen Observatorium zu Potsdam, Germany. His death comes as a great blow to astronomical science, as he was one of the most industrious, resourceful, and productive investigators, in spite of the fact that his health had been rapidly failing during recent years. His achievements, well-known to every student in astronomy, will serve as his monument in ages to come. The members of the Society will recall with satisfaction the glowing tribute paid to VOGEL by our past President, Professor TOWNLEY, at the annual meeting in the year 1906, in bestowing upon him the Bruce Medal in behalf of the Society.[1]

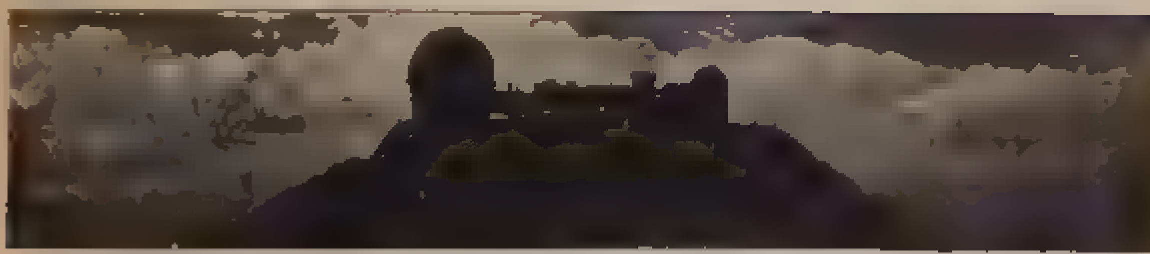
Those of us who had the rare fortune of a closer personal acquaintance with him learned to admire his noble character no less than his immortal services to astronomy. VOGEL, first of all, was a man in the true sense of the word, an astrophysicist next. Kind to those who sought his help and advice, charitable in controversy with those who held opposing views in scientific matters, loyal to his staff, generous to his co-workers, faithful and self-sacrificing towards his students, he endeared himself to all who came in contact with him.

It is a source of deep satisfaction to the Astronomical Society of the Pacific that in making its last award of the Bruce Medal to VOGEL it had the opportunity of expressing to the distinguished deceased the high esteem in which his name was held in this country.

A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, Oct. 2, 1907.

[1] Address of the Retiring President of the Society in Awarding the Bruce Medal to Geheimer Ober-Reg. Rath Professor Doctor HERMANN CARL VOGEL. By SIDNEY DEAN TOWNLEY. *Publications A. S. P.*, Vol. XVIII, No. 107.



NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTES ON THE ECLIPSE EXPEDITION TO FLINT ISLAND.

The personnel of the Crocker Eclipse Expedition to Flint Island will consist of Director CAMPBELL, Astronomer PERRINE, Astronomer AITKEN, Assistant ALBRECHT, of the Lick Observatory Staff, and Professor E. P. LEWIS, of the Department of Physics of the University of California. The observers of the Smithsonian Institution Expedition will consist of Director C. G. ABBOT and Mr. ALFRED MOORE, of the University of California. The carpenter, two workmen, cook, and cook's assistant will bring the total number up to twelve, to which the Commander of the U. S. gunboat "Annapolis" desired the party to be limited.

The expedition expects to sail from San Francisco on November 22d, and return on January 25th.

F. K. MCCLEAN, Esq., of Tunbridge Wells, England, expects to carry an expedition to Flint Island in a chartered vessel. It will be a pleasure for us to have him and his colleagues as associates on the island.

Meteorological data collected during the month of January, 1907, are very encouraging. The eclipse will occur at about 11:18 A.M. At this hour of the day the sky was clear and fine on about twenty-two days in the month.

MT. HAMILTON, September 23, 1907. W. W. CAMPBELL.

SPECTRA OF THE LIMB AND CENTER OF THE SUN.

In a comparative study of the spectrum of the Sun at the center and near the limb, the following points of difference have been found:—

1. The great majority of the lines that are strengthened in sun-spots are strengthened near the limb.
2. The great majority of the lines that are weakened in spots are weakened near the limb.

3. Most of the lines are slightly widened.
4. The wings of diffuse lines are greatly reduced.
5. In agreement with HALM, most of the lines are shifted toward the red.
6. The amount of the shift varies for different lines of the same element.
7. The lines of the ultra-violet cyanogen fluting are not shifted.

In general, while the results so far obtained point to increased effective pressure near the limb (HALM's explanation) as the probable cause of the line-shifts, judgment is reserved until the completion of laboratory experiments now in progress.

September, 1907. GEORGE E. HALE, and WALTER S. ADAMS.

PRELIMINARY PHOTOGRAPHIC MAP OF THE SUN-SPOT SPECTRUM.

A photographic map, extending from λ 4600 to λ 7200, and consisting of 26 sections of 100 Angströms each, has recently been made by Mr. ELLERMAN from the Mt. Wilson negatives of sun-spot spectra. The original negatives were made with the Littrow-grating spectrograph, of eighteen feet focal length, used with the Snow telescope. Each section of the spot spectrum, after being enlarged on a plate moving in the direction of the lines (by the pendulum process frequently employed for widening stellar spectra), is printed alongside the corresponding region of the normal solar spectrum. An approximate scale of wave-lengths, merely for the identification of lines, and not for the determination of their positions, also appears on each section. It is expected that a more perfect map can be issued later. This is intended to supply the immediate needs of visual observers of spot spectra, and has been placed in the hands of those who are taking part in the work set on foot by the International Union for Co-operation in Solar Research.

GEORGE E. HALE.

September, 1907.

SIX STARS WHOSE RADIAL VELOCITIES VARY.

The following stars have been shown to have variable radial velocities, by photographs taken with the Mills spectrograph at Mt. Hamilton. The approximate range of speed observed

is given in the second column, and the names of the discoverers in the third:—

Star.	Observed Range.		Observed by
o Tauri	— 15 to	— 24^{km}	MOORE.
f Tauri	+ 9	+ 27	MOORE.
η Camelopardalis	+ 22	— 40	MOORE.
A Boötis	— 11	— 40	MOORE.
β Coronæ	— 15	— 33	MOORE.
ξ Cygni	— 19.6	— 24.1	CAMPBELL.

W. W. CAMPBELL,
J. H. MOORE.

TWO STARS WHOSE RADIAL VELOCITIES ARE VARIABLE.

Professor WRIGHT, formerly in charge of the D. O. Mills Expedition to the Southern Hemisphere, has found from their variable velocities that the following stars are spectroscopic binaries:—

x Carinæ, with observed speed lying between + 3.3^{km} and + 17.4^{km} per second.

ι Gruis, with observed speed lying between — 2.3^{km} and — 18.8^{km} per second.

The photographs upon which these discoveries were based were taken at Santiago, Chile, by Messrs. WRIGHT and PALMER in 1904-1905, and by Dr. CURTIS in 1906-1907.

W. W. CAMPBELL.

NOTE ON THE PUBLICATIONS OF THE LICK OBSERVATORY.

In the past years six quarto bound volumes of the *Publications* of the Lick Observatory have been printed and distributed to our correspondents.

Volume VII of the *Publications* will contain articles written by members of the Berkeley Astronomical Department. Parts 1, 2, and 3, relating to a short method of determining orbits, were printed in 1902. Only a few copies were mailed, to those who were especially interested in the subject, and the remainder of the edition was held with the expectation that the succeeding parts of the volume would be published soon and be included in the bound volume. Delay in completing the volume makes it desirable that these parts should be distributed unbound in the near future, following the completion of Parts 4 and 5, now ready to go to press.

Volume VIII of the *Publications*, to contain photographs of nebulæ and star clusters secured by the late Director KEELER and by Dr. PERRINE, has been in preparation for three years past. In common with the experience of others, difficulties have been encountered in securing satisfactory reproductions of the photographs. It has been found necessary to compromise between pictorial effects and strict scientific values, and a fair rate of progress has been made during the past year. It is hoped that means will be found in the near future to make several complete sets of positives on glass of these photographs for deposit with leading scientific societies in various centers of population, in order to make them available to all investigators who desire to study them in detail.

Volume IX of the *Publications* relates to the work of the D. O. Mills Expedition to the Southern Hemisphere. Parts 1, 2, and 3 have just been mailed to our correspondents. They include an account of the organization and history of the expedition by Director CAMPBELL, and a description of the instruments and methods by Acting-Astronomer WILLIAM H. WRIGHT, in charge of the expedition. The spectrograms secured by the expedition will have been measured and reduced in the course of a few months, and it is planned to publish the results for the 145 stars included in the programme as promptly as possible.

Volume X of the *Publications* is more than half through the press. It contains the results of meridian-circle observations by Astronomer R. H. TUCKER. The bound volume will be mailed before the end of the present year.

It is the intention to send out all completed volumes in bound form.

W. W. CAMPBELL.

MT. HAMILTON, September 23, 1907.

A FIREPROOF BUILDING ON MT. HAMILTON.

The construction of the half of a fireproof building is under way at the present time. It is not expected that the second half of the building will be constructed before the summer of 1909. The first half will contain, on the first floor, storage vaults for the valuable and extensive collection of observatory photographs, together with the records and computations for all the observations, visual as well as photographic, and such valuable smaller instruments as are not in daily use. The

second floor will consist of a photographic-enlarging room, fifty feet in length in the clear, provided with graduated steel track to carry the lenses and cameras used in this work. It is expected that these rooms will be available for occupation about January 1st.

W. W. CAMPBELL.

MT. HAMILTON, September 23, 1907.

IMPROVEMENTS TO THE CROSSLEY REFLECTOR.

Mr. F. G. PEASE, recently assistant to Professor G. W. RITCHEY, and now optical expert to The Scientific Shop, Chicago, spent a month on Mt. Hamilton figuring a convex hyperbolic mirror for the Crossley reflector, in order to convert it into the Cassegrain form with an equivalent focal length of seventy-five feet. The corresponding mechanical additions are in course of construction by the Lick Observatory instrument-maker. It is hoped to utilize the Cassegrain form in parallax and spectrographic researches.

MT. HAMILTON, September 23, 1907. W. W. CAMPBELL.

RECENT PROGRESS IN THE CONSTRUCTION WORK OF THE SOLAR OBSERVATORY.

The figuring of the 60-inch mirror was completed by Professor RITCHEY in August, the residual errors not exceeding one tenth of a wave. The final tests were made with the aid of parallel light furnished by a 36-inch plane mirror, also figured in our optical-shop during the year. The various convex and plane mirrors required for the 60-inch reflector when used in the Newtonian and Cassegrainian forms are now being completed.

The mounting for this telescope will soon be finished in our instrument-shop. It is being assembled in Pasadena, and will be thoroughly tested there before being set up on Mt. Wilson.

The Mt. Wilson road was finished in May, and much of the structural steel for the building and dome of the 60-inch reflector has been taken to the summit. The erection of the building is advancing rapidly under the supervision of Mr. GEORGE D. JONES, who also completed the road.

The vertical cœlostat telescope, of twelve inches aperture and sixty feet focal length, has been erected on the mountain, and will be tested in September. The cœlostat and second mirror support by BRASHEAR and the 30-foot Littrow-grating

spectrograph by GAERTNER are in position, and the two plane mirrors, each twelve inches thick, have been figured by Professor RITCHEY.

GEORGE E. HALE.

September, 1907.

PROFESSOR JULIUS'S VISIT TO MT. WILSON.

As the outcome of a plan arranged two years ago, Professor W. H. JULIUS, of the University of Utrecht, has recently spent some weeks on Mt. Wilson. The prime object of his visit was to discuss the possible bearing of anomalous dispersion on astrophysical phenomena, in the hope that definite criteria might be found, capable of settling the question. A series of investigations has now been planned, covering both solar and laboratory work, and will be carried out as soon as possible.

While on Mt. Wilson Professor JULIUS employed the five-foot spectroheliograph to photograph the anomalous-dispersion phenomena of sodium vapor, which resemble the solar flocculi. This work, as well as the numerous discussions of the anomalous-dispersion theory, was a source of great pleasure and profit to all the members of the staff.

September, 1907. GEORGE E. HALE.

NEW APPOINTMENTS TO THE STAFF OF THE MT. WILSON SOLAR OBSERVATORY.

Professor J. C. KAPTEYN, of the University of Groningen, will hereafter spend several months of each year at Mt. Wilson, and take charge of such parallax and other similar work as may be done in connection with his "Plan of Selected Areas." So far as possible, the working programme of the 60-inch reflector will be arranged so that the photographs, both direct and spectroscopic, will be of service for Professor KAPTEYN'S studies of stellar distribution, as well as for the prime purpose of the observatory—the investigation of stellar evolution. This can easily be done by giving preference to KAPTEYN'S areas when undertaking general spectrographic surveys or in studying the smaller spiral nebulæ. In addition, certain nights will be set apart for his special purposes. The direct bearing, on the one hand, of KAPTEYN'S important researches on the problem of stellar evolution, and the need, on the other, of a large reflector to furnish the data he desires for the fainter

stars, promise valuable returns from this co-operative undertaking. Professor KAPTEYN will commence work on Mt. Wilson as soon as the 60-inch reflector is ready for use, probably in the summer of 1908.

Dr. ARTHUR L. KING, of the University of California, will take charge of the physical laboratory of the Solar Observatory as soon as he can relinquish the duties of his present position, probably in January, 1908. It is proposed to undertake an extensive investigation of anomalous-dispersion phenomena, and the effects of temperature and pressure, for lines which will also be studied in sun-spots, at the center and limb of the Sun, in the chromosphere, and in stars of various types. Dr. KING will be assisted in the laboratory by Dr. OLMSTED, who has been engaged in similar work at Mt. Wilson during the past year.

GEORGE E. HALE.

September, 1907.

REQUEST FOR UNPUBLISHED OBSERVATIONS OF THE VARIABLE STAR *U GEMINORUM*.

Mr. J. VAN DER BILT, Astronomer at the observatory, Utrecht, Holland, has undertaken the definitive reduction of all available observations of this remarkable variable, and would be very glad to have copies of any unpublished observations, in such detail that they can be reduced by a normal photometric light-scale. They may be sent to him direct. Address Maliesingel 58, Utrecht; or if sent to the undersigned, they will be transmitted to him.

YERKES OBSERVATORY,
WILLIAMS BAY, WISCONSIN.

J. A. PARKHURST.

CHANGES IN THE STAFF OF LICK OBSERVATORY.

Mr. KEIVIN BURNS, Carnegie Assistant during the past four years, with duties in the measurement and reduction of stellar spectrograms, resigned, to take effect October 1st, in order to pursue postgraduate studies.

Dr. B. L. NEWKIRK, Carnegie Assistant during the past year, resigned, to take effect September 1st, to accept appointment as Assistant Professor of Mathematics and Mechanics in the College of Engineering, University of Minnesota.

HENRY C. PLUMMER, M. A., Assistant in the University of Oxford during the past six years, has been appointed a Fellow

in the Lick Observatory. His time will be devoted to work in the spectroscopic department.

Miss LEAH ALLEN, of Brown University, Providence, Rhode Island, has been appointed Carnegie Assistant with duties in the measurement and reduction of spectrograms.

MT. HAMILTON, September 23, 1907. W. W. CAMPBELL.

EPHEMERIDES FOR THE WATSON ASTEROIDS.

In accordance with the intention expressed in *Lick Observatory Bulletin* No. 114, to provide regularly ephemerides for coming oppositions of the various asteroids discovered by WATSON, as far as the progress made in determining their elements and first order perturbations by *Jupiter* may permit, ephemerides were computed by Miss GLANCY from the elements and perturbations derived under my direction in the Berkeley Astronomical Department, for the recent oppositions of (103) *Hera* and (179) *Klytæmnestra*. Unfortunately, these ephemerides were not completed in time for publication in a *Lick Observatory Bulletin*. A photographic position of *Hera* was secured, however, by Miss GLANCY, at this observatory on June 14th, and requests for observations of (179) were sent to Director CAMPBELL, of the Lick Observatory, and to Admiral WALKER, Superintendent of the United States Naval Observatory.

At the Lick Observatory three observations were secured by Mr. DUNCAN, on September 18th, 19th, and 20th, and Professor EICHELBERGER, of the Naval Observatory, has communicated to me a correction to the ephemeris of (179), based on an observation by Mr. HAMMOND, taken September 23d. In each case the ephemerides were given to 1^s and $0'.1$. The agreement between theory and observation is far better than was expected. The correction to the ephemeris of (103) on June 14th, is $+0^s.6$ and $-0'.3$. The correction to the ephemeris of (179), communicated by Professor EICHELBERGER for September 23d, is $+2^s$ and $-0'.1$. The mean correction, however, to the ephemeris of (179) from the Lick observations, September 19th, is 0^s and $-0'.1$.

The last opposition upon which the elements of (179) are based occurred eight years ago. A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, Oct. 2, 1907.

Courses in Astronomy.

The first term of the academic year 1907-1908 has opened with an increased enrollment in the courses in Practical Astronomy. There are now forty-six students engaged in night work. Of these twenty-two take the course 4B, especially intended for civil engineers; eight are enrolled in 4A, a course designed for students who have chosen astronomy for their profession; and sixteen in Astronomy 2, a general course offered to students as a culture study. Other enrollments during the current term are: General Astronomy, ninety-five; Least Squares, thirty-six; Interpolation, Numerical Integration, and Differentiation, six; Theoretical Astronomy (Graduate), three; Celestial Mechanics (Graduate), four. Of the graduate students, four are men and three women. In the undergraduate courses there is a notable increase this year in the percentage of men. The number of well-prepared, capable, and serious students in the various courses is also noteworthy. In view of the increased enrollment in the practical courses, the university has granted the department an additional assistant. Applications for the newly created position should be sent without delay to the Director of the Students' Observatory.

A. O. Leuschner.

Berkeley Astronomical Department, Oct. 2, 1907.

GENERAL NOTES.

Deaths.—During the last few months astronomy in central Europe has suffered a severe blow through the loss of four persons closely associated with the progress of the science in recent years. The *Astronomische Nachrichten,* No. 4190, contains three obituary notices. In the last number of these *Publications* brief mention was made of the death of Dr. EGON VON OPPOLZER, professor of astronomy at Innsbruck. Dr. OPPOLZER, son of the noted astronomer THEODORE VON OPPOLZER, author of the celebrated "Lehrbuch zur Bahnbestimmung der Kometen und Planeten," was born in Vienna on October 13, 1869, and died June 15, 1907, being therefore less than thirty-eight years of age. His education was obtained at the universities of Vienna and Munich. For a time he served as an assistant in the observatory at Prague, and in 1901 was made associate professor of astronomy at Innsbruck, and professor in 1906. Dr. OPPOLZER was an enthusiastic investigator, and made many contributions to the science of astronomy along various lines. He made investigations concerning the Earth's atmosphere and solar phenomena. He was also interested in photography and photometry, and will be remembered as the discoverer of the short-period variability in the brightness of the planet *Eros.* During the last few years Dr. v. OPPOLZER was engrossed in the building and equipping of a new observatory at Innsbruck, nearly the whole cost of which was paid out of his own pocket. The equipment was designed especially for work in spectroscopic and photographic lines, and was almost ready for use when the hand of death intervened to bring to a sudden close the life and work of an ardent searcher for truth.

On June 29th Professor SIEGFRIED CZARPSKI, Director of the Carl Zeiss firm, makers of the celebrated Zeiss lenses and optical instruments, died in Jena at the age of forty-six years. Although not an astronomer by profession, yet Dr. CZARPSKI, through his connection with the optical works and through attendance upon the meetings of the Astronomische Gesellschaft, came into contact with many of the astronomers of Europe. When a young man he was a student under HELMHOLZ, and through the recommendation of that master became

private assistant to Professor ABBE. The balance of his life was spent in Jena. Dr. CZARPSKI's chief contribution to science is a book on geometrical optics, called "Theorie der Optischen Instrumente nach ABBE."

On July 13th Dr. HEINRICH KREUTZ, associate professor of astronomy at the University of Kiel and editor of the *Astronomische Nachrichten*, passed away, after a long illness, at the age of fifty-two years. His preparation for the astronomical profession was obtained at the University of Bonn under the tutorship of SCHÖNFELD and KRUEGER. After further study in Vienna under WEISS and OPPOLZER, he became a computer in the Recheninstitut at Berlin. Dr. KREUTZ soon gave up this position, however, in order to accept the position of observer and computer at the Kiel Observatory when Professor KRUEGER was called there in 1883 to become director of the observatory and editor of the *Astronomische Nachrichten*. In this position KREUTZ became familiar with editorial work, and was naturally chosen to succeed KRUEGER in the editorship of the *Nachrichten* when the latter died, in 1896. The laborious duties of this position were performed with great care, and Professor KREUTZ succeeded in maintaining the high standard previously enjoyed by the *Nachrichten* as the leading astronomical journal of the world. Dr. KREUTZ was especially interested in the investigation of orbits of comets, and carried to completion several very extensive pieces of computation. The most important of these were investigations of the orbits of the comets 1843 I, 1861 II, 1880 I, 1882 II.

Another severe loss to astronomy came through the death on August 13th of Professor HERMANN CARL VOGEL, Director of the Astrophysical Observatory at Potsdam. Dr. VOGEL was the sixth Bruce medalist of the Astronomical Society of the Pacific, and reference to his life and work will be found on another page of this number of the *Publications*.

Notes from "Science."—MARY W. WHITNEY, professor of astronomy at Vassar College, and president of the Nantucket Maria Mitchell Association, spent a week lately at the Maria Mitchell Memorial on Nantucket, giving instructive talks to members and their guests on "Maria Mitchell" and on "Recent Discoveries in the Solar System." Professor WHITNEY has appointed a building committee to consider plans for an observ-

atory to house properly an equatorial telescope recently donated to the association. Already the sum of $2,138 has been subscribed, and the association in charge of the memorial hopes for subscriptions to enable it not only to house the telescope but also to equip the observatory so that it may be available for astronomical classes in the near future.

Sir David Gill's Address.—The presidential address of Sir DAVID GILL, delivered before the annual meeting of the British Association for the Advancement of Science at Leicester, has been printed in full in *Science* for August 16th. The address is highly interesting and instructive, and should be read by every one interested in astronomy.

Doctor's Degrees.—In *Science* for August 30th there is an article entitled "Doctorates Conferred by American Universities." During the last ten years the degree of Doctor of Philosophy and Doctor of Science (not including honorary degrees) has been conferred upon 2,715 persons, and of these 1,232 were taken in the sciences. Thirty-four degrees have been granted in astronomy, which stands ninth among the twenty sciences enumerated. Three doctorates in astronomy were conferred during the last academic year, as follows: By Columbia University, on ANNE SEWELL YOUNG, "The Stellar Clusters *h* and χ *Persei*; Measurement and Reduction of the Rutherford Photographs"; by the University of California, on JAMES DAVIS MADDRILL, "A Study of Several Stars of the δ *Cephei* Type"; by the University of Virginia, on FRANK WALKER REED, "Singular Points in the Approximate Development of the Perturbative Function."

NEW PUBLICATIONS.

AMBRONN, L. J., and R. Sternverzeichnis enthaltend alle Sterne bis zur 6.5tn Grösse für das Jahr 1900.0. Berlin: J. Springer. 1907. Large 8vo. x + 183 pp. Cloth.

CAMPBELL, W. W. A list of Lick Observatory negatives from which lantern-slides and transparencies can be supplied. Sacramento. 1907. 8vo. 21 pp. Paper.

COWLEY, ELIZABETH B., and WHITESIDE, IDA. Definitive orbit of Comet 1826 II. Kiel: Astronomische Abhandlungen als Ergänzungshefte zu den Astronomischen Nachrichten, Nr. 13. 1907. 4to. 18 pp. Paper.

DYSON, F. W. Determinations of wave-length from spectra obtained at the total solar eclipses of 1900, 1901, and 1905. London: Memoirs of the Royal Astronomical Society, appendix to Vol. LVII. 1906. 4to. 50 pp. Boards.

HUGGINS, Lady. Agnes Mary Clerke and Ellen Mary Clerke: An appreciation. London: Printed for private circulation. 1907. 8vo. 54 pp. Cloth.

LANGLEY, SAMUEL PIERPONT. Memorial meeting, December 3, 1906. Addresses by Doctor White, Professor Pickering, and Mr. Chanute. Washington; Smithsonian Miscellaneous Collections, No. 1720. 1907. 8vo. 49 pp. Paper.

PALISA, JOHANN. Katalog von 3,458 Sternen für das mittlere Aequinoktium 1875.0. Vienna. 1906. 4to. xii + 95 pp. Paper.

SCHORR, R. Tafel der Reductions-Konstanten zur Berechnung scheinbarer Sternörter für die Jahre 1850 bis 1860. Hamburg: Mitteilungen der Hamburger Sternwarte, Nr. 9. 1907. Large 8vo. viii + 230 pp. Paper.

SCHWARZSCHILD, K. Ueber die totale Sonnenfinsternis von 30 August, 1905. Göttingen: Astronomische Mitteilungen der K. Sternwarte zu Göttingen, 13 Teil. 1906. 4to. 73 pp. Plates. Paper.

TAYLOR, H. DENNIS. A system of applied optics. London: Macmillan & Company. 1906. Royal 8vo. 16 + 334 pp. Cloth.

VOGEL, H. C. Die zwei Doppelrefraktoren des Observatoriums. Potsdam: Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Band 15, erstes Stück. 1907. 4to. 59 pp. Plates. Paper.

Berliner Astronomisches Jahrbuch für 1909. Berlin: Ferd. Dümmler. 1907. 8vo. x + 615 pp. Paper.

Connaisance des temps, pour l'an 1909. Paris: Gauthier-Villars. 1907. 8vo. viii + 931 pp. Paper. 4 francs.

Memoire del R. Osservatorio Astronomico al Collejio Romano. Series III, Vol. IV, Parte II. Rome: 1907. 4to. 285 pp. Paper.

Proceedings (The) of the optical convention, No. I. London. 1905. London: Norgate and Williams. Royal 8vo. vi + 247 pp. Cloth, 10 s.

Publications of the Lick Observatory.[1] Volume IX, Parts 1, 2, and 3. Sacramento. 1907. 4to. 70 pp. Paper.

[1] See note on page 241.

Minutes of the Meeting of the Board of Directors, Held at the Lick Observatory, Mt. Hamilton, on September 14, 1907, at 8 p.m.

President Cushing presided. The following directors were present: Aitken, Campbell, Crawford, Cushing, Richardson, Townley, and Ziel. The minutes of the last meeting (July 13, 1907) were approved.

The Librarian reported many more generous responses to the circular letter concerning the library.

A reply, acknowledging with thanks the receipt of the award of the Donohoe comet-medal, from Professor H. Thiele was read.

The Library Committee was authorized to procure a card-catalogue case and an accessions-book.

On behalf of the Committee on the Donohoe Comet-Medal Professor Campbell, chairman, reported the following awards:—

To Giacobini for the discovery of Comet *a* 1907; to Mellish for the discovery of Comet *b* 1907; to Giacobini for the discovery of Comet *c* 1907; to Daniel for the discovery of Comet *d* 1907.

The resignation of Dr. Newkirk from the Publication Committee was accepted with regret.

Dr. James D. Maddrill was elected to fill the vacancy on the Publication Committee, *vice* Newkirk resigned.

The Committee on Meetings, consisting of Messrs. Campbell, Leuschner, and Townley, was continued, and requested to report at the next meeting.

The following was elected to membership:—

B. L. Hodghead, 601 Merchants Exchange, San Francisco.

The following was elected an institutional member:—

Library of University of Washington, Seattle, Wash.

The following were elected corresponding members:—

Library of Solar Observatory, Mt. Wilson, Cal.

Flower Observatory, University of Pennsylvania, Upper Derby, Pa.

The following resolution was introduced and passed unanimously:—

Resolved, That the bonds belonging to this Society be deposited in trust with the Mercantile Trust Company of San Francisco, a corporation, the said Trust Company to collect the interest and pay the same as it accrues to the Treasurer of this Society, the said bonds to be delivered by said Trust Company only as directed by this Society, the intention of the Society to remove the same from the custody of said Trust Company to be evidenced by a resolution of the Board of Directors, under seal of this corporation, and duly certified by the President, or a Vice-President, and the Secretary of the Society.

Be it further Resolved, That the President and Treasurer of this Society are hereby authorized to take all necessary steps to carry this resolution into full force and effect, including, if necessary, the indorsement by them of any of the bonds belonging to this Society.

A vote of thanks to the Director and Staff of the Lick Observatory for their invitation and hospitality at this meeting was passed unanimously.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr CHAS. S CUSHING . . . . *President*
Mr A H BABCOCK . . . . *First Vice President*
Mr W W CAMPBELL . . . . *Second Vice President*
Mr GEO E. HALE . . . . *Third Vice President*
Mr R T CRAWFORD (Students Observatory Berkeley) *Secretary*
Mr R G AITKEN (Mount Hamilton, Cal) . . . . *Secretary*
Mr F R ZIEL . . . . . *Treasurer*

Board of Directors Messrs. AITKEN, BABCOCK, BURCKHALTER, CAMPBELL, CROCKER, CRAWFORD, CUSHING, HALE RICHARDSON, TOWNLEY, ZIEL.

Finance Committee—Messrs RICHARDSON CROCKER BURCKHALTER.

Committee on Publication Messrs AITKEN, TOWNLEY, MADDRILL

Library Committee—Messrs. CRAWFORD. IRVING, TOWNLEY

Committee on the Comet Medal Messrs. CAMPBELL (ex-officio), BURCKHALTER, PERRINE.

NOTICE.

The attention of new members is called to Article VIII of the By Laws, which provides that the annual subscription, paid on election covers the calendar year only Subsequent annual payments are due on January 1st of each succeeding calendar year This rule is necessary in order to make our bookkeeping as simple as possible Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied Members are requested to preserve the copies of the *Publications* of the Society as sent to them Once each year a title page and contents of the preceding numbers will also be sent to the members who can then bind the numbers together into a volume Complete volumes for past years will also be supplied to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries Any non-resident member within the United States can obtain books from the Society's library by sending his library card, with ten cents in stamps to the Secretary A S P, Students Observatory, Berkeley, Cal who will return the book and the card

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience In a general way, those papers are printed first which are earliest accepted for publication Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. **It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the** views expressed in the papers printed, and for the form of their expression rests with the writers, and is not assumed by the Society itself

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society at cost price, as follows a block of letter paper, 40 cents of note paper, 25 cents a package of envelopes, 25 cents. These prices include postage and should be remitted by money order or in U S postage **stamps. The sendings are at the risk of the member.**

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with The Secretary Astronomical Society of the Pacific " Students' Observatory, Berkeley, Cal, in order that arrangements may be made for transportation, lodging, etc

PUBLICATIONS ISSUED BI MONTHLY.

(February, April, June, August, October, December.)

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, DECEMBER 10, 1907. No. 117.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1908.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

New Moon.....Jan. 3, $1^h 43^m$ P.M.			New Moon....Feb. 2, $12^h 36^m$ A.M.	
First Quarter... " 10, 5 53 A.M.			First Quarter... " 8, 8 27 P.M.	
Full Moon...... " 18, 5 37 A.M.			Full Moon...... " 17, 1 5 A.M.	
Last Quarter.... " 26, 7 1 A.M.			Last Quarter... " 24, 7 24 P.M.	

The first of the three solar eclipses of the year will occur on January 3d. It will be a total eclipse, the line of totality running through the Pacific Ocean from a point north of Australia to the east coast of Central America. It will be seen as a partial eclipse from points in the central and southern parts of the United States late in the afternoon. The path of totality is mainly over the open ocean, but it crosses several of the small islands in the South Pacific, which afford fairly good observing stations. Some of these will be made use of by observing parties from the Lick and other observatories. The maximum duration of totality is a little more than four minutes; this is rather more than the average duration. One circumstance is perhaps worth noting. As the line of the eclipse track crosses the line "where the day begins," the local time of beginning is sunrise of January 4th, and the local time of ending is sunset on January 3d.

The Earth is in perihelion on the morning of January 2d.

Mercury is a morning star at the beginning of the year, too near the Sun for naked-eye observations, as it rises only half an hour before sunrise. It passes superior conjunction on the evening of January 13th, reaches greatest east elongation on February 13th, and comes to inferior conjunction on February

28th. At the time of greatest elongation it remains above the horizon rather more than an hour and a half after sunset, and it will be an easy object for naked-eye view on a clear evening during the late twilight. The interval between the setting of the Sun and of the planet is more than an hour during the period from two weeks before to about one week after the date of greatest elongation. The duration of visibility and maximum elongation from the Sun are both much less than the average for winter east elongations, for the reason that the planet passes its perihelion less than a day after the time of greatest elongation. There will be a much better opportunity for seeing the planet in June.

Venus is an evening star, gradually increasing its distance from the Sun from 29°, on January 1st, to 36°, on February 29th. On the first-named date it sets a trifle more than two hours after sunset, and this interval increases to more than three hours by the end of February. On the evening of February 13th it will be within one degree of the point in the sky known as the vernal equinox. It passes *Saturn* about noon on February 10th, a little more than one degree, or two apparent diameters of the Moon, north of the latter.

Mars will not be in good position for observation throughout the year on account of its distance from us and consequent faintness, although it will not be difficult to see it except for a month or two about the middle of the year, while it is near conjunction with the Sun. On January 1st it is an evening star, and remains above the horizon until nearly 11 o'clock, and by the end of February it sets a little before $10^h\ 30^m$. During the two-months period it moves about 38° eastward and 17° northward through the constellation *Pisces* into *Aries*, passing a little north of the vernal equinox on January 10th. On January 1st its distance from the Sun will be 127 millions of miles. This is more than three times as great as the distance at the time of opposition in July, 1907, and its brightness will be not one tenth as great as it was then; but it will still be as bright as all but the brightest stars, and there is no star as bright in near proximity to the planet, although it is quite close to *Saturn* on January 1st. So there will be no difficulty in identifying it. Its distance from the Earth is increasing rapidly, and it will lose more than half its brightness by the end of February.

Jupiter is in fine position for observation, as it comes to opposition with the Sun on January 29th. It will then be above the horizon throughout the whole night, and during the whole two-months period it will be in sight whenever the twilight is sufficiently dark to show it. It is in the constellation *Cancer,* not very near any bright star, and retrogrades, moves westward, about 10°, and 2° northward by February 29th.

Saturn is an evening star, setting a little after $10^h\ 30^m$ on January 1st, and a little after 7^h on February 29th. At the beginning of January it is near *Mars,* about 2° south, but its slower motion among the stars makes the distance between the planets increase rapidly, and by the end of February it is more than 30°. The very interesting series of appearances and disappearances of the rings which has been going on during 1907 ceases early in January. On January 1st the Earth and Sun are on opposite sides of the plane of the rings, but in a few days the Earth passes to the other side of the plane, and for the following fourteen or fifteen years Earth and Sun will both be on the southern side. For some months the rings will present the appearance of a very narrow streak, but in the summer of 1908 the apparent minor axis will be about one eighth of the major.

Uranus is in conjunction with the Sun on January 4th and becomes a morning star, but does not get far enough away for visibility until after the end of the period. It is so faint —just within the limit of naked-eye visibility—that it cannot be seen without a telescope at a much lower altitude than 25°.

Neptune is in opposition with the Sun on January 4th, and is therefore above the horizon throughout the whole night at that time, but it is too faint for naked-eye observation. It is in the constellation *Gemini.*

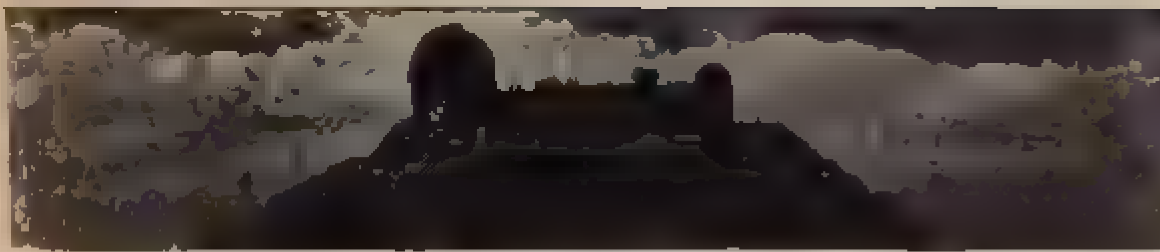
NOTICES TO MEMBERS.

The next number of our Publications is to contain the new membership list. The Committee on Publication requests the members to notify the Secretary of any changes of address from those given in Publications No. 112.

* * *

The library has at its disposal a fund made up of contributions sent in response to the Society's circular letter asking for help in building up a new library. This money is to be expended for the purchase of books of a popular nature. In order that we may get such books as the members of the Society desire, the Librarian hereby requests them to send to him suggestive lists of books. The only books of a popular nature at present in our library are:—

CLERKE. Problems in Astrophysics.
CLERKE. The System of the Stars.
HOVESTADT. Jena Glass.
HOWE. Elements of Descriptive Astronomy.
HUGGINS. The Royal Society.
IRVING. How to Know the Starry Heavens.
LANGLEY. The New Astronomy.
WEBB. Celestial Objects for Common Telescopes.
YOUNG. General Astronomy.



NOTES FROM PACIFIC COAST OBSERVATORIES.

ORBIT OF THE SPECTROSCOPIC BINARY θ *DRACONIS*[1]

The binary nature of this star was discovered by Director CAMPBELL and announced in 1899. In the interval from March, 1898, to July, 1904, thirty two plates were secured that could be used to measure the radial velocity of the star. These were all measured by the writer at Mt. Hamilton, and from the results preliminary elements were computed graphically by the formulæ of LEHMANN FILHES. These elements were corrected differentially by a least-squares solution which gave the following set of final elements:—

$$\begin{aligned} \text{Period} &= 3.0708 \quad \pm 0.000032 \text{ days} \\ e &= 0.0141 \quad \pm 0.0166 \\ T &= \text{J. D. } 2415368.962 \quad \pm 0.499 \text{ days} \\ \omega &= 126^\circ.112 \quad \pm 58^\circ.6 \\ k &= 23.47 \quad \pm 0.324 \end{aligned}$$

Velocity of system $= -8.36^{km} \pm 0.30^{km}$

$a \sin i = 9{,}900{,}000^{km}$.

SANTIAGO, CHILE, June, 1907. HEBER D. CURTIS.

THE ORBITS OF THE SPECTROSCOPIC BINARIES *a CARINÆ*, *κ VELORUM*, AND *a PAVONIS*.

The binary character of *a Carinæ* and *κ Velorum* was detected by Professor W. H. WRIGHT in the course of the work of the D. O. Mills Expedition to the Southern Hemisphere. The binary character of *a Pavonis* was also suspected by him from preliminary measures of the first four plates taken, and was independently discovered from the definitive reductions of the same plates by Dr. S. ALBRECHT.

The three stars are of the same general spectral type described as Type B 3 A in the Harvard classification. In

[1] The details of this orbit are published in *Lick Observatory Bulletin* No. 122.

the part of the spectrum covered by the spectroscope of
Mills reflector, only six lines are measurable. It is the c
ion of the writer that the application of the method of
squares to stars of this type of spectrum and number of
is not warranted except in the case that a large numbe
observations are available, extending over a long interv
time. Preliminary elements were therefore first derived gr
ically by the formulæ of LEHMANN-FILHES. Changes
then made in the derived elements, after comparing with
curve given by the observations, and several sets of elen
tested by the observation values. With some experienc
this method it is possible in a relatively short time to test
change the elements given by the graphical solution unti
resulting values would be little if any bettered by a l
squares solution.

By such methods the following sets of elements
derived:—

	a Carinæ	*κ Velorum*	*a Pavon*
Period =	6.744 days	116.65 days	11.753 d
$e =$	0.18	0.19	0.01
$k =$	21.5	46.5	7.25
$T =$	J. D. 2416533.81	2416459.00	241637
$\omega =$	115°.84	96°.23	224°.80
Velocity of system =	$+ 23.3^{km}$	$+ 21.9^{km}$	$+ 2.0^{km}$
$a \sin i =$	1,060,000^{km}	73,200,000^{km}	1,170,00

Details of the observations and residuals are given in
Observatory Bulletin, No. 122.

HEBER D. CURT

THE D. O. MILLS EXPEDITION,
SANTIAGO, CHILE, June, 1907.

NOTE ON COMET *c* 1907 (MELLISH).

Comet *c* 1907 was discovered on the morning of Oc
14th by JOHN E. MELLISH, of Cottage Grove (near M
son), Wisconsin, in R. A. 8^h 31^m, Decl. −9° 24′. It
visible with an opera-glass.

From the first three available observations (October
by HARTWIG, at Bamberg; October 16th, 17th, by DUN
at Mt. Hamilton) a preliminary orbit was computed by
fessor CRAWFORD, Miss GLANCY, and Miss MORGAN.
elements and an ephemeris are given in *Lick Observatory
letin*, No. 121.

On the basis of observations giving a longer arc (October 15th, by HARTWIG, at Bamberg; October 19th, 30th, by DUNCAN, at Mt. Hamilton) a second orbit was computed by Professor CRAWFORD and Miss GLANCY. A part of this computation was checked by Miss MORGAN. The elements and ephemeris extending to the end of this year are published in *Lick Observatory Bulletin,* No. 124.

The two orbits (both parabolic) differ very little from each other. The longitude of the node is 55°; the longitude of the perihelion is 350°. The motion in the orbit is retrograde, the inclination of the orbit plane to the ecliptic being 120°. The comet passed perihelion on September 14th, at a distance of 91,000,000 miles from the Sun. It was nearest to the Earth on November 11th, and at that time was distant 38,000,000 miles, having a theoretical brightness three times as great as on the day of discovery. The comet is now receding from both the Sun and the Earth. It is a matter of interest that the observed brightness of the comet to date has not agreed with the computed brightness.

A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, November 20, 1907.

ECLIPSE EXPEDITION.

The Lick Observatory Crocker Eclipse Expedition left Mt. Hamilton on November 18th, and sailed from San Francisco for Tahiti on the steamship Mariposa on November 22d. From Tahiti the party is to be conveyed to Flint Island, about four hundred miles north, by means of a U. S. naval vessel. It is expected that the party will arrive at Flint Island about December 5th, which will allow four weeks in which to erect the instruments and to make the necessary preparations for the event. Flint Island lies at about 12° south latitude, and is several miles south of the central line of the eclipse shadow. The eclipse is to occur at about $11^h\ 18^m$, local mean time, and totality will last about four minutes.

The party consists of Director CAMPBELL, Astronomers PERRINE and AITKEN, and Assistant ALBRECHT of the Lick Observatory, and Professor E. P. LEWIS of the University of California. They expect to again reach San Francisco about January 25th.

SIDNEY D. TOWNLEY.

Mr. W. F. MEYER, a graduate of Drake University, has been appointed assistant in astronomy in the Berkeley Astronomical Department of the University of California.

NOTE ON COMET *a* 1907 (GIACOBINI).

A telegram has just been received stating that WOLF observed this comet on December $4^d.4364$ Gr. M. T., in right ascension $3^h\ 23^m\ 40^s$ and declination $+50°\ 35'$. This place is represented very closely by the orbit computed by Mr. EINARSON, Miss GLANCY, and Miss JOY, from observations extending from March 9th to April 9th. This orbit was published in *Lick Observatory Bulletin*, No. 113. The residuals in α and δ for the above position are (O–C) $+13^s$ and $-3'$ respectively.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, December 7, 1907.

GENERAL NOTES.

On the Constancy of Wave-Length of Spectral Lines.—The October number of the *Astrophysical Journal* contains a translation of a recent article by Professor KAYSER, in which he disposes of the question of the supposed variability of wave-length with variation of circumstances. The following sentences are extracts: "An extensive literature has already grown up on the question whether the wave-lengths of spectral lines are invariable or whether they depend on the mode of production of the spectrum, whether the density of the vapor has any effect, etc. . . . The importance of this question in terrestrial and astronomical spectroscopy leads me to make some remarks on the subject. . . . I am convinced that the differences which different observers obtain for the same line are due to the fact that they start from different standards which do not agree with each other. . . . The fact that with the same standards an accuracy of a few thousandths of an Ångstrom unit is attained, while with different standards only as many hundredths of a unit, led the International Solar Union to place upon its programme the more precise determination of the standards as one of the most pressing problems . . . At the meeting of the Union in Paris in May, Professor AMES was able to communicate the fact that Dr. PFUND had made experiments in his laboratory with the interferometer, which proved that the wave lengths are precisely the same, regardless of whether the spectrum was produced in the spark or in the arc, at atmospheric pressure or in a vacuum, of pure metals or of an alloy or salts. This was true without exception for all the elements investigated. Professor FABRY declared that his experiments had yielded precisely the same result. Inasmuch as the most precise method which we have was employed here, we must regard these experiments as decisive, and consider that the question of the constancy of the wave lengths is finally settled."

Notes from "Science."—A. N. SKINNER, professor of mathematics, U. S. N., of the U. S. Naval Observatory, was retired according to law upon reaching the age of sixty-two years, on

August 12, 1907. Professor SKINNER will remain upon active duty, however, until the completion of some unfinished work on the Astronomische Gesellschaft zone — 14° to — 18°, which was observed under his direction from 1892 to 1894. H. L. RICE, formerly assistant astronomer at the observatory, has been appointed to the professorship vacated by this retirement, and H. R. MORGAN succeeds Mr. RICE in the position of assistant astronomer. The organization of the work of the observatory has been changed in the direction of the consolidation of the work, and Professor W. S. EICHELBERGER, U. S. N., has been placed in charge of all the astronomical work of the observatory.

The Committee of the French Academy of Sciences having scientific control of the French geodetic operations on the equator has reported the completion of the remeasurement of the historic arc in Peru.

M. MAURICE LOEWY, director of the Paris Observatory, born in Vienna in 1833, died on October 15th, while attending a meeting of the national board of French observatories of the Ministry of Public Instruction.

Dr. RALPH H. CURTISS, formerly of the Lick and more recently of the Allegheny Observatory, has been appointed assistant professor of astrophysics in the University of Michigan.

Asaph Hall.—The death is announced of ASAPH HALL, professor of mathematics U. S. N. (retired). Professor HALL was born at Goshen, Conn., October 15, 1829. The early years of his manhood were devoted to teaching school, and it was not until he had reached the mature age of twenty-eight years that his astronomical career was begun as student and assistant at Harvard College Observatory. He entered the Naval Observatory in 1862, and remained in continuous connection with that institution until his retirement in 1891. Professor HALL had the use of the 26-inch refractor at the Naval Observatory, which, at the time it was completed, was the largest refractor in the world. His attention was given chiefly to the measurement of double stars and the satellites of the solar system. Professor HALL also investigated the orbits of several of the satellites, but his name will be longest remembered as the discoverer of the two tiny moons of *Mars*.

Dr. Elis Strömgren, Privatdozent in the University of Kiel, has been appointed professor and Director of the observatory in Copenhagen, in the place of Professor T. N. Thiele, who has retired.

NEW PUBLICATIONS.

Cookson, Bryan. Determination of the elements of the orbits of *Jupiter's* satellites from photographs taken at the Cape in 1902. Edinburgh. 1907. 4to; 122 pp. Paper. 3s.

Dunér, N. C. Ueber die Rotation der Sonne, zweite Abhandlungen. Upsala: Akademische Buchhandlung. 1907. 4to; 64 pp. Paper.

Hedrick, H. B. Catalogue of zodiacal stars for 1900 and 1920 reduced to an absolute system. Astronomical papers prepared for the use of the American Ephemeris and Nautical Almanac, Vol. VIII, Part III. Washington: Bureau of Equipment, Navy Department. 1905. 4to; 190 pp. Paper.

Kamenskij et E. Korolikov. Les éléments approchés et l'éphéméride de la comète d'Encke. Bulletin de l'Académie Impériale des Sciences. St. Petersburg. 1907. Large 8vo; 8 pp. Paper.

A catalogue of 420 standard stars mostly between 31° and 41° south declination for the equinox 1905.0, from observations made at the Perth Observatory, Western Australia, under the direction of W. Ernest Cooke. Perth. 1907. 4to; 13 pp. Cloth.

Astronomical and magnetical and meteorological observations made at the Royal Observatory, Greenwich, in the year 1905. Edinburgh. 1907. 4to. Cloth.

Etude de l'atmosphère. Observatoire Constantin. Fascicule II. St. Petersburg. 1906. 4to; ix + 45 + 92 pp. Paper.

Minutes of the Meeting of the Board of Directors, Held in Room 601, Merchants Exchange, San Francisco, Cal., on November 30, 1907, at 2 P. M.

The following directors were present: Burckhalter, Crawford, Cushing, Richardson, Townley, Ziel. Directors Aitken, Babcock, Campbell, and Hale were represented by proxies.

President Cushing presided. The minutes of the meeting of September 14, 1907, were changed by substituting "corresponding institutions" for "corresponding members," and then approved.

The Bruce Medal for 1907 was awarded.

The following were elected to membership:—

Dr. Thos. Porter, 1111 Washington Street, Oakland, Cal. (temporary address).

Mr. Morgan Sanders, 1419 West Lanvale Street, Baltimore, Md.

The following was elected an institutional member:—

Public Library, Seattle, Wash.

It was moved, seconded, and carried, that the temporary publication address of the Society be 601 Merchants Exchange, San Francisco, Cal.

The Librarian reported briefly upon the present state of the Library.

Adjourned.

Minutes of the Meeting of the Society, Held in Room 601, Merchants Exchange, San Francisco, Cal., on November 30, 1907, at 2:30 P. M.

President Cushing presided. Upon calling the Society to order he announced that the meeting would be devoted to informal discussion of current astronomical problems.

Professor Leuschner gave a brief history and an account of the present state of the work on the Watson asteroids, which has been carried on at Berkeley for the last seven years.

Professor Townley made a few remarks on astronomical work at Stanford University, and also gave a brief account of the more recent work on the variation of latitude.

Mr. Burckhalter called attention to some recent observations of an unusual character that he had made upon the rings of *Saturn*.

A general discussion was had upon Professor Lowell's article on *Mars* in the December (1907) *Century*.

Adjourned.

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NOTICE.

The attention of new members is called to Article VIII of the By Laws, which provides that the annual subscription paid on election, covers the calendar year only Subsequent annual payments are due on January 1st of each succeeding calendar year This rule is necessary in order to make our bookkeeping as simple as possible Dues sent by mail should be directed to Astronomical Society of the Pacific Students' Observatory, Berkeley

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries Any non resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S P., Students Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience In a general way those papers are printed first which are earliest accepted for publication Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States The responsibility for the views expressed in the papers printed and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper 40 cents, of note paper, 25 cents, a package of envelopes 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps The sendings are at the risk of the member

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation lodging, etc

PUBLICATIONS ISSUED BI MONTHLY

(February, April June, August October, December)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco California Subscription price $5.00 per year

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OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.

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SAN FRANCISCO:
PRINTED FOR THE SOCIETY.
1908.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XX. SAN FRANCISCO, CALIFORNIA, FEBRUARY 10, 1908. No. 118

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Williams Bay, Wisconsin, Yerkes Observatory.
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FOR REVIEW.

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LORD KELVIN.

By H. C. Plummer.

The death of Lord Kelvin, which occurred in the closing days of the past year, concerns primarily that science the progress of which he did so much to mould, but also, in a scarcely less degree, all those sciences which are largely dependent on the development of the fundamental principles of natural philosophy, and among these not least astronomy. A dominant figure among men of science throughout the latter half of the nineteenth century, and, since the death of v. Helmholtz, in 1894, beyond dispute the greatest living physicist, he has passed away in the full fruition of his genius at the venerable age of eighty-three years. Those who had the privilege of listening to him so lately as last August at the Leicester meeting of the British Association will not easily forget his inspiring example or how perfectly his mental powers were maintained to the end of his long life. Indeed, the mature power manifested in his early youth, the youthful enthusiasm of his old age, and the life of unwearied achievement which lay between, are alike remarkable in a brilliant career.

William Thomson was born at Belfast in June, 1824. His father, at that time professor of mathematics in the Belfast Academical Institution, was called, eight years later, to fill the chair of mathematics in Glasgow University. This was the beginning of that long and memorable association with the ancient Scottish seat of learning which enabled Lord Kelvin to say truly, on the occasion of his installation as Chancellor three years ago: "I am a child of the University of Glasgow. I lived in it sixty seven years (1832 to 1899)." In the same address he has drawn a fascinating picture of the university in the thirties, and of his own early studies there. His precocious abilities were truly astonishing, and there can be no doubt but that he had the good fortune to be placed in an environment which fostered them to the utmost. He was matriculated in 1834, at the age of ten, and studied Latin under William Ramsay, Greek under Sir Daniel Sandford and Lushington, logic under Robert Buchanan, and moral philosophy under William Fleming. From his father he

learned mathematics and much else besides, from WILLIAM COUPER zoology and geology, and from THOMAS THOMSON chemistry. The latter, "a very advanced teacher and investigator," had already realized a well-equipped laboratory, which preceded LIEBIG'S famous laboratory at Giessen. As regards his indebtedness to his teachers in natural philosophy, Lord KELVIN'S own tribute may be quoted: "My predecessor in the natural philosophy chair, Dr. MEIKLEHAM, taught his students reverence for the great French mathematicians, LEGENDRE, LAGRANGE, LAPLACE. His immediate successor in the teaching of the natural philosophy class, Dr. NICHOL, added FRESNEL and FOURIER to this list of scientific nobles; and by his own inspiring enthusiasm for the great French school of mathematical physics, continually manifested in his experimental and theoretical teaching of the wave theory of light and of practical astronomy, he largely promoted scientific study and thorough appreciation of science in the University of Glasgow." The youthful student made splendid use of splendid opportunities; he repaid them by lifelong devoted service and added luster to an illustrious foundation.

The years that followed at Cambridge seem only an incident in the career of one who had already read something of the "Théorie analytique de la Chaleur" before his sixteenth birthday. WILLIAM THOMSON was second wrangler in the tripos of 1845, and first Smith's Prizeman in the same year. He was immediately elected to a fellowship at his own college, Peterhouse, but he was not destined to remain at Cambridge. In the following year, after working for a time at Paris, in the laboratory of REGNAULT at the Collége de France, he was elected, at the age of twenty two, to succeed Dr. MEIKLEHAM in the chair of natural philosophy at Glasgow. This office he filled continuously for fifty three years, until his resignation in 1899.

Space forbids a detailed reference to the brilliant and many-sided work of original discovery which Lord KELVIN crowded into this memorable period of scientific history. Much is matter of common knowledge; many excellent notices have been published since his death, and it is understood that an authentic biography by Professor SILVANUS THOMPSON is to appear shortly. Even if the view is restricted to the astronomical standpoint, and an attempt is made to appraise the

debt which astronomy owes to Lord KELVIN's work, the points of direct contact and of indirect influence are so manifold that they enforce his own dictum, that all science is one science and that any part of science which places itself outside the pale of the other sciences ceases for the time being to be a science. Thus he served the cause of submarine telegraphy alike by the theoretical discussion of the conditions of the problem, by the invention of practical receiving apparatus, and by his indomitable scientific faith at a time when AIRY declared an Atlantic cable to be on mechanical and electrical grounds impossible; and while the realization of the cable is a benefit to humanity at large, the astronomer incidentally owes to it the fact that the ocean has been no longer a barrier to accurate determinations of longitude. The mirror galvanometer, again, which constituted his earlier form of receiving apparatus, has found innumerable applications; perhaps its most direct service to astronomy is to be seen in LANGLEY'S use of it as an essential part of his bolometer. These examples are quoted merely to show that there is scarcely any part of Lord KELVIN's activity which is not of interest to the astronomer. His researches covered the whole field of electricity and magnetism, ranging from developments in the subject of electrostatics, with the beautiful theory of images, to the invention of numerous instruments for precise measurement, used in every physical laboratory and by every electrical engineer, and so perfectly designed as to remain unchanged even in detail.

For work in the theory of heat Lord KELVIN was particularly well fitted by his early training and by his association, brief though it was, with REGNAULT. He was also fortunate in the friendship and co-operation of JOULE. In this field some of his best and most original work was done, both on the theoretical and the experimental side. By his restatement of the second law of thermodynamics, by his definition of an absolute thermodynamic scale of temperature, and by his discovery of the principle of the dissipation of energy, he is entitled, along with CLAUSIUS, to rank as one of the founders of thermodynamics. On the experimental side his best work was the "porous-plug experiment" carried out in conjunction with JOULE, and his researches in thermo-electricity, including the discovery of the "Thomson effect." By applying the analysis of FOURIER to the consideration of the thermal con-

dition of the Earth, Lord KELVIN was led to announce his famous limit to its possible age as a habitable planet This brought about the celebrated conflict with the uniformitarians, and has exercised a profound influence on the thoughts of geologists The opposing views were never entirely reconciled, and the question at issue has been reopened by the recent discovery of sub-atomic sources of energy. The same question is also involved to some extent in Sir GEORGE DARWIN'S theory of the evolution of the Earth-Moon system.

The problem of the age of the Earth is only one aspect of that presented by the mechanical energies of the solar system which in all its generality occupied Lord KELVIN'S attention from an early date. He first examined the theory that the heat of the Sun was maintained by the influx of meteoric matter from outer space, and rejected it after a careful quantitative estimate on the ground that the number of meteors required to supply the loss of heat by solar radiation is enormously in excess of what is compatible with terrestrial experience. He then adopted the suggestion of v. HELMHOLTZ, that the energy emitted in a radiant form was gained by the contraction of the Sun's mass at the expense of gravitative potential energy. This doctrine, to which HOMER LANE contributed in this country, led him to investigate the conditions of a spherical mass of gas in convective equilibrium. There are many obstacles in the way of adapting this theory to actual stellar conditions, and the difficulty of drawing definite conclusions has not been diminished by the new possibilities presented by the energy set free in radio active transformations; but of the suggestive importance of the theory there can be no doubt

Many investigations were made by Lord KELVIN in the region of hydrodynamics, and his work on tides is of great importance To him and to Sir GEORGE DARWIN is due the fact that tidal theory is now practically perfect The part which he took in devising mechanical means for calculating tides resulted in a practical labor-saving machine for predicting the tides of the Indian Ocean He also designed a tide recorder and a harmonic analyzer Graphical and mechanical methods of performing calculations, and in particular of solving differential equations, possessed much interest for him, and it may be noted that the method of mechanical quadratures employed by Sir GEORGE DARWIN in his memoir on Periodic

Orbits is the numerical counterpart of a graphical method described by Lord KELVIN. Of great interest to the astronomer are his researches regarding the physical condition of the Earth, in which, by masterly use of the results of tidal observations and of the theory of nutation, he arrived at definite conclusions as to the rigidity of the external and internal substance of the Earth. The stimulus derived from personal intercourse with Professor NEWCOMB led him farther to examine the possible variation in the diurnal period and axis of rotation, some fifteen years before the accurate observations of Professor KUSTNER and the comprehensive discussions of Dr CHANDLER had revealed the true nature of the problem of the variation of latitude.

Lord KELVIN was himself a keen yachtsman, and to the art of navigation he has rendered immense services by applying his inventive genius to its needs. By observing true scientific principles he invented and manufactured the standard type of mariner's compass. His apparatus for sounding by means of pianoforte wire is as simple as it is effective. As regards the astronomical side of the seaman's art, he advocated the use of SUMNER'S method for finding a ship's place at sea, and published tables to facilitate its application. Here it may be recalled that he wrote several papers on chronometers and clocks, including electrical controls, especially an important one in which he discussed the effect on the rate of the form of suspension. One contribution he made to purely practical astronomy: this was a photometric study of the Sun and Moon and a comparison of their light with terrestrial standards.

In conjunction with the late Professor TAIT, Lord KELVIN wrote the classic "Treatise on Natural Philosophy," which was translated by v. HELMHOLTZ, and has been used as a text book perhaps even more extensively in Germany than in England. The responsibility for the abbreviated title, "T and T′" has been variously assigned. The breadth of view and the stimulating interest of these two volumes must cause a regret that a scheme so brilliantly begun was not carried farther. But it is matter for satisfaction that Lord KELVIN lived to amplify and to publish his "Baltimore Lectures" twenty years after the date of their delivery (in 1884) at the Johns Hopkins University. Here are to be found in a collected form the final results of his researches in molecular dynamics and the wave

theory of light, more particularly concerning the dynamical theory of dispersion. Of late years much of his thought was devoted to the ultimate structure of matter and the true nature of the æther. It would be idle to pretend that his views on these matters towards the end of his life gained very general assent. The *i* which he persistently retained in the word "electrion" seemed symbolical of a certain divergence on his part from the main stream of contemporary thought. And indeed his death significantly marks an epoch in scientific history. The school of which he was so brilliant an example was not content with anything less than a complete dynamical explanation of phenomena. This phase of scientific positivism is passing away, and the tendency since the publication of CLERK MAXWELL'S electromagnetic theory has been unmistakably, if perhaps too hastily, more and more in the direction of "æther and no matter," to quote Professor LAMB'S parody of the title of Professor LARMOR'S book.

Yet, if the whole of Lord KELVIN'S ideas are not destined to find acceptance, his possible weakness is closely allied to the great source of his strength, his passion for the concrete. The man who makes no mistake makes nothing, and no man ever more ruthlessly destroyed the creatures of his own fertile brain, when he deemed them to have become erroneous or useless, than Lord KELVIN. Of him v. HELMHOLTZ wrote thirty years ago: ". . . he has done very much to destroy the old unnatural separation between experimental and mathematical physics, and to reduce the latter to a precise and pure expression of the laws of phenomena. He is an eminent mathematician, but the gift to translate real facts into mathematical equations, and *vice versa*, is by far more rare than that to find the solution of a given mathematical problem, and in this direction Sir WILLIAM THOMSON is most eminent and original." It has been denied that he is to be regarded as a mathematician in the strict sense. It is true, perhaps, that in his own branch he was not the equal in this respect of v. HELMHOLTZ himself, or of STOKES, to mention no others; but the complete denial of his claim rests upon the restriction of the word "mathematics" to the pure variety. As a logical distinction this may be harmless enough, but if the idea is extended in the region of education to the practical separation of the pure and applied branches the result is likely to be unfortunate

for both. There is little doubt that without the due cooperation of the two the Cambridge school of mathematical physicists would have been shorn of its chief glories.

Lord KELVIN had traveled widely and had made several visits to this country. The last was in 1902, when he received a generous and enthusiastic welcome, which will be within the memory. Some of the impressions which he received during a visit in 1876 are recorded in his presidential address to Section A of the British Association in the same year, and some of his words on that occasion may be of interest:—

". . . I wished to write an address of which science in America should be the subject. I came home, indeed, vividly impressed with much that I had seen, both in the great exhibition of Philadelphia and out of it, showing the truest scientific spirit and devotion, the originality, the inventiveness, the patient persevering thoroughness of work, the appreciativeness, and the generous open-mindedness and sympathy, from which the great things of science come. . . .

"I wish I could speak to you of the veteran HENRY, generous rival of FARADAY in electromagnetic discovery; of PEIRCE, the founder of high mathematics in America; of BACHE, and of the splendid heritage he has left to America and to the world in the United States Coast Survey; of the great school of astronomers which followed, GOULD, NEWTON, NEWCOMB, WATSON, YOUNG, ALVAN CLARKE, RUTHERFORD, DRAPER, father and son;" nor does the passage end here. Only those who have heard Lord KELVIN speak will be able to realize the glow of enthusiastic sincerity with which such a tribute would be uttered.

Many years ago it was said that "in Sir WILLIAM THOMSON the most brilliant genius of the investigator is associated with the most lovable qualities of the man. His single-minded enthusiasm for the promotion of knowledge, his wealth of kindliness for younger men and fellow-workers, and his splendid modesty, are among the qualities for which those who know him best admire him most" These qualities were only enhanced with advancing years Withal, he was endowed with the shrewd business capacity of his race, and not only personally supervised the manufacture of his numerous patents but also acted as a director of several public companies. He was conservative to the core—and that not merely in the

political sense. This is to be seen in his strict adherence to NEWTON'S formal enunciation of the principles of dynamics, though his colleague TAIT was more outspoken in his denunciation of any departure from the Newtonian position. The advocates of the retention of compulsory Greek in the ancient universities were also able to quote in their favor an opinion bearing all the weight of Lord KELVIN'S authority, and, it may be added, in the light of his early training, of his personal experience.

Great and varied were his talents, and worthily he used them for the benefit of mankind. All the successes, all the honors, that could fall to the lot of a man of science were his. He was president of the British Association in 1881, and in succession to Sir GEORGE STOKES was president of the Royal Society from 1890 to 1895. Nowhere will his presence be more keenly missed than at the annual meetings of the British Association, which he attended so assiduously. His connection with his own University of Glasgow was crowned by his election as Chancellor in 1904. On his return from the laying of the first successful Atlantic cable, in 1866, his services to the state were rewarded with a knighthood; later, in 1892, he was raised to the peerage under the title of Baron KELVIN of Largs. When the Order of Merit was instituted by King Edward, in 1902, he was chosen as one of the first members of that select band. Other decorations, British and foreign, were showered upon him. The learned societies of his own and other countries had done him such honor as lay within their power. And the last solemn distinction which England has to bestow was reserved for him. Amid a scene which the December gloom of a London day served only to render the more impressive, in the presence not only of representatives of the King, of foreign governments, of the whole world of learning, but also of vast numbers who must have felt a deep sense of personal loss, he was laid to rest in Westminster Abbey. There he finds a place in close proximity to him whom he would be the first to acknowledge as his master, ISAAC NEWTON. His fame is secure in the comprehensive influence which he exercised on the scientific progress of his generation; his is the *"monumentum ære perennius."*

ASTRONOMICAL OBSERVATIONS IN 1907.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris*.[1]

Jan.	4:	S { < e. > f.
	8:	id.
	11:	id.
Feb.	16:	2 steps > g.
Mar.	5:	= h.
	24:	1 step < h.
Apr.	3:	{ > g. < f.
	10:	= f.
	19:	{ < e. > f.
	23:	id.
May	11:	1 step < e.
July	6:	3 steps > d.
	16:	2 steps > d.
Aug.	5:	= e.
	21:	{ < e. > f.
Aug.	26:	= f[1].
	30:	= f.
Sept.	4:	id.
	8:	{ < f. > g.
	11:	id.
	12:	id.
	15:	id.
	17:	1 step > g.
	24:	= g.
	28:	< g.
Oct.	5:	= h.
	12:	id.
	25:	invisible.
Nov.	13:	id.
	29:	1 step > f[1].
Dec.	29:	{ in the midst between d and e.

[1] Vide the sketch in the *Publications A. S. P.*, No. 73, p. 56.

T *Ursæ Majoris*.[1]

Jan.	4:	T invisible.
	8:	id.
	11:	id.
Feb.	16:	< g.
Mar.	5:	{ > f. < e.
	24:	{ > c. < b.
Apr.	2:	{ > b. < a.
	3:	id.
	10:	{ > b. almost = a.
	19:	= a.
	23:	2 steps > a.
May	11:	= a.
July	6:	1 step < e.
	16:	id.
Aug.	5:	1 step < f.
	26:	very faint.
	30:	id.
Sept.	4:	id.
	8:	id.
	11:	id.
	12:	id.
	15:	id.
	17:	id.
	24:	invisible.
	28:	id.
Oct.	5:	id.
	12:	3 steps < f.
	25:	{ > f. < e.
Nov.	13:	2 steps > d.
	29:	3 steps > a.
Dec.	29:	5 steps > a.

[1] Vide the sketch in the *Publications A. S. P.*, No. 22, p. 63.

W *Pegasi*.[2]

Jan. 4:	W = b.
11:	id.
Feb. 16:	< c. > d.
Aug. 26:	utmost faint.
30:	1 step < g.
26:	> g. < f.
28:	= f.
Oct. 5:	in the midst between f and e.
Oct. 6:	id.
12:	id.
25:	1 step > e.
Nov. 5:	= d.
13:	in the midst between d and c.
29:	in the midst between c and b.
Dec. 29:	b (3) W (2) c.

[2] Vide the sketch in the *Publications A. S. P.*, No. 60, p. 23.

SS *Cygni*.[1]

Jan. 4, 7^h:	SS = g.
8, 8^h:	id.
11, 6^h:	= c.
Sept. 4, 9^h:	1 step < g.
10, 9^h:	< g.
13, 9^h:	id.
24, 8^h:	invisible.
26, 8^h:	< g.
28, 8^h:	invisible.
Sept. 30, 11^h:	< g.
Oct. 5, 10^h:	1 step < g.
6, 8^h:	id.
12, 8^h:	id.
25, 8^h:	> c. < b.
Nov. 29, 6^h:	< g.
Dec. 29, 6^h:	1 step < g.

[1] Vide the sketch in the *Publications A. S. P.*, No. 100, p. 18.

Y *Tauri* (B. D. + 20° 1083).

Jan. 8:	Y < A. > b.
11:	1 step > b.
Mar. 5:	= b.
Apr. 3:	id.
Apr. 19:	= A.
Aug. 21:	1 step > A.
Oct. 5:	= A.
Nov. 29:	id.
Dec. 29:	id.

As comparison-stars I have used A = B. D. + 20° 1095 ($7^m.4$) and b = B. D. + 20° 1073 ($8^m.2$). This irregular variable star has had its greatest brightness, in the summer of 1907.

Meteors.

Fireballs have been observed at the following dates: January 11th, 12th, 14th, February 15th, March 4th, May 14th, July 16th, October 18th, November 6th, 7th, 20th, 26th, December 5th, 25th.

Shooting-Stars.

Shooting-stars have been observed from eight stations in Denmark and Norway in the period August 9th 11th Only on August 11th the weather was favorable. At these stations 170 paths of shooting-stars were mapped, but only three proved suitable for calculation. These three meteors have given the following results:—

For Observation.

Time.	Station	Beginning.	Ending.	Mag.	Observer
g. 11, 10^h 52^m 30^s P.M.	Nyborg	100° + 55°	111° + 50°.5	2	Ch. Frost.
	Vallo	148 + 54	159 + 44	1	J F. Nielsen
g. 11, 11 34 14 P.M.	Sonderborg	1 + 66 .5	357 + 57	2	Maria Wolff.
	Vallo	249 + 24 .5	253 + 18	2	J. F Nielsen
g. 11, 11 47 0 P.M.	Odder	2 + 12	356 + 2	2	T Köhl.
	Nyborg	12 + 33	4 + 25	1	Ch. Frost

For Calculation.

No.	Beginning.			Ending.			Real Length of the Path.	Radiant.	
	h	λ	φ	h	λ	φ	β	A R	Decl.
1	73.5	1° 14′.3 W	56° 52′.3	45.1	1° 34′.2 E	56° 37′.2	45.3	50°	+61°
2	91	2 15.9 W	55 13.9	82	2 11.7 W	55 4.9	19.4	157	+60
3	104	0 6.1 W	55 15.7	77	0 31.3 W	55 5.3	44.1	44	+52

h and *β* are expressed in kilometers; λ is longitude from Copenhagen, φ is north latitude; *h* is the altitude of the meteor above the Earth's surface.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1908.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon.	March 2, 10^h 57^m A.M.		First Quarter	April 8,	8^h 31^m A.M.
First Quarter	" 9, 1 42 P.M.		Full Moon	" 16,	8 55 A.M.
Full Moon	" 17, 6 28 P.M.		Last Quarter	" 23,	11 7 A.M.
Last Quarter	" 25, 4 32 A.M.		New Moon	" 30,	7 33 A.M.
New Moon	" 31, 9 2 P.M.				

The vernal equinox, the time when the Sun passes from the south to the north side of the equator, occurs on March 20th, at 4 P.M., Pacific time.

Mercury passed inferior conjunction on February 28th, becoming a morning star, and continues to be a morning star

until May 7th. It reaches its greatest west elongation on March 27th, and its apparent distance from the Sun is then 27° 49′. The planet reaches its aphelion on the following day, and therefore this apparent distance from the Sun is much greater than the average maximum elongation; but the planet is then 12° south of the Sun and rises only a little more than one hour before that body. This interval remains about the same throughout the latter half of March. It may be possible to see the planet in the early morning twilight if the air near the horizon is exceptionally clear, but it will not be an easy object. *Mercury* and *Saturn* are in very close conjunction at about noon on April 14th, the least distance being only 28′, less than the Moon's apparent diameter; but the planets are then only 18° from the Sun, and rise considerably less than an hour before sunrise.

Venus is an evening star, and is the most conspicuous object in the western sky in the evening. For several months it has been gradually moving out toward greatest east elongation, and reaches it on April 26th. Its distance from the Sun is then 45° 37′, not quite the maximum possible, as the planet passed perihelion on April 1st; but the planet at the end of April is at its greatest distance above the plane of the Earth's orbit as seen from the Sun, and nearly at its greatest distance above as seen from the Earth. This causes the setting of the planet to be considerably delayed, and during the entire month of April the planet remains above the horizon nearly four hours after sunset, nearly an hour longer than at the average greatest elongation. The greater part of this increase is, however, due to the fact that this greatest east elongation comes in the spring, while the planet's declination is 10° or more greater than that of the Sun. *Venus* and *Mars* are in conjunction on April 4th, at 7 A.M., Pacific time, the former passing 1° 37′ north of the latter.

Mars still remains an evening star, but is gradually being overtaken by the Sun in their common eastward motion, the distance between them diminishing from 50° on March 1st to 37° on April 30th. The time of the planet's setting at the end of the two months' period is half an hour earlier than at the beginning, changing from $10^h\ 22^m$ P.M., on March 1st, to $9^h\ 50^m$ P.M., on April 1st. The planet moves among the stars about 42° eastward and 10° northward through *Aries*

into *Taurus.* On April 1st it is less than 5° south of the *Pleiades*, and on April 20th it is about 6° north of *Aldebaran*, the first-magnitude red star of the *Hyades* group in *Taurus* Its actual distance from the Earth is still rapidly increasing—about forty million miles during the two months, and it will lose considerably in brightness; but there will be no difficulty in recognizing it, although by this time it will not be as bright as the brightest stars.

Jupiter still remains in fine position for evening observation, being in plain view until 5 A.M. on March 1st, and until 1 A.M on April 30th. It is on the meridian, well up toward the zenith, at about 10 P.M. on March 1st, and at about 6 P.M on April 30th It is nearly stationary in the constellation *Cancer*, moving slowly westward until March 20th, and then moving eastward, but the whole motion is only about one half degree.

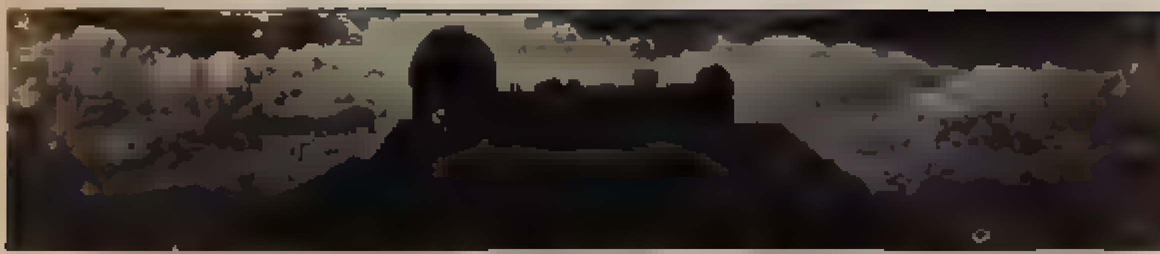
Saturn is too near the Sun for easy visibility, except at the beginning and end of the period On March 1st it sets about an hour and a half after sunset, but its distance from the Sun diminishes rapidly, and it comes to conjunction on the evening of March 20th. After that it is a morning object, but even at the end of April it rises less than an hour and a half before sunrise It is not bright, like *Venus*, and it will not be a very easy matter to see it at any time during March and April

Uranus is an early-morning object on March 1st, too near the Sun to be seen; but the Sun draws away from it rapidly and the planet rises much earlier toward the end of the period—about midnight on April 30th It is in the eastern part of *Sagittarius* north and east of the "milk-dipper." No bright stars are near to make identification easy.

Neptune is in the evening sky, not setting until after midnight It is in the western part of the constellation *Gemini*

SEVENTH AWARD OF THE BRUCE MEDAL.

At a meeting of the Board of Directors of the Astronomical Society of the Pacific, held on November 30, 1907, the Bruce Gold Medal of the Society was awarded to Professor EDWARD C. PICKERING, director of Harvard College Observatory, for distinguished services to astronomy. Professor PICKERING'S letter accepting the honor may be found near the end of this number, under the minutes of the meeting of the Board of Directors held on November 30th. The presidential address, reviewing the life and works of the seventh recipient of the Bruce Medal, will be delivered at the annual meeting of the Society, to be held on March 28th.



NOTES FROM PACIFIC COAST OBSERVATORIES.

A Comparative Study of the Spectra of the Limb and Center of the Sun.

[ABSTRACT]

Solar spectra, corresponding to points at the center and near the limb of the Sun's disk, were photographed side by side on the same plate with a Littrow or auto-collimating spectrograph of eighteen feet focal length, used in conjunction with the Snow telescope of the Mt. Wilson Solar Observatory. The third or fourth orders of a four-inch plane grating, having 14.438 lines to the inch, were employed. For the measurement of line displacements, spectra were photographed at points near the limb lying at opposite ends of a solar diameter, thus permitting the rotational shifts to be eliminated Some of the more recent work has been done with a Littrow spectrograph of thirty feet focal length, used with the new vertical cœlostat or "tower" telescope of the Solar Observatory. This instrument is of the same focal length as the Snow telescope (60 feet), and thus the diameter of the solar image is about 6.7 inches in each case. The four-inch grating, when used with the thirty-foot spectrograph, gives a scale of $1^{mm} = 0.58$ Ångstroms in the third order and $1^{mm} = 0.44$ Ångstroms in the fourth order. As the Fraunhofer lines are fairly sharp on the photographs, this great scale permits a high degree of precision to be attained in their measurement. Up to the present time most of the work has been done in the region λ 3800–λ 5800. It is therefore quite possible that the preliminary results given in this paper may not apply below *D*, or in the ultra-violet. These results may be summarized as follows:—

1. Most of the lines shown by our photographs of spot spectra to be strengthened or weakened in sun-spots, are similarly affected near the limb.
2. Many lines not affected in spots are strengthened or weakened near the limb.
3. Lines due to substances of high atomic weight are, in general, greatly weakened near the limb.

4. Winged lines undergo marked change in appearance, the wings being greatly reduced near the limb.
5. Among the lines considerably strengthened near the limb the most important are due to elements of comparatively low atomic weight. These include the *D* lines of sodium, the *b* lines of magnesium, and the blue calcium line at λ 4227.
6. Most of the lines in the spectrum are slightly widened near the limb.
7. Most of the lines are shifted toward the red, as compared with their position at the center of the Sun.
8. These displacements are not due to ascending currents at the center of the Sun (which would produce negative displacements of the lines in the solar comparison spectrum), since they have also been measured with the aid of an arc comparison spectrum.
9. The magnitude of the shift varies for different lines of the same element.
10. The strengthened lines, as a rule, seem to show smaller shifts than do the other lines.
11. The spark lines of a given element, as a rule, show larger shifts than do the other lines.
12. In many cases the relative displacements of the lines agree fairly well with those obtained by HUMPHREYS in his laboratory experiments on the effect of pressure on wave-length.
13. The lines of the cyanogen flutings (λ 3883.5 and λ 4216.14) are not shifted from their normal positions.
14. The shifts of groups of titanium lines near λ 3900, λ 4500, and λ 5300, and of groups of iron lines near λ 3800, λ 4400, λ 4900, and λ 5500, show progressive increase toward the red, and seem to indicate that the average pressure shift, for similar lines, is a function of the wave-length.
15. Photographs taken at intermediate points between center and limb indicate that the shifts fall off rapidly, and become very small at a short distance from the limb.

As our investigation is being continued, we reserve a discussion of these results, and their bearing on the earlier work of HALM, for a future paper.

GEORGE E. HALE.
WALTER S. ADAMS.

Note on Riefler Clock.

The new Riefler clock delivered to the observatory in the fall of 1906, and started in late November, differs from the rest of the observatory clocks in three essential particulars,—namely, in having a nickel-steel, compensated pendulum, in the construction and operation of its motive apparatus, and in its arrangement for constant pressure.

The first of these differences gives a metallic bar pendulum instead of the usual mercury pendulum. This becomes possible through the invention of a combination of nickel and steel the coefficient of expansion of which is exceedingly small.

The arrangement for supplying the motive power shows the greatest departure from old lines. Three Edison-Lalande cells, connected in series and regulated by a rheostat, supply the power for lifting the driving weight of the clock. This weight, about ten grams, is pivoted at one end, and at the other engages, with a pawl, a wheel directly connected with what is known as the third wheel in clocks of the ordinary winding devices. When the weight has finished its fall, it completes the battery circuit and is lifted again by an electromagnetic lever. The relation between the weight lifted and the strength of the battery is such that the intervals between lifts may vary from 28^s to 34^s. If it becomes less than 28^s, a little falling off in battery strength will result in failure to wind. Since it can fall from the highest possible position in 34^s, any attempt to increase the battery strength beyond the amount necessary to raise it to this point only produces a violent contact at the top of its lift. A daily note of this interval gives a check on the battery strength and a warning when to lessen the resistance in the rheostat. The device works very smoothly.

To secure a constant pressure, the entire clock is mounted inside a heavy cylindrical glass case consisting of two parts, the perfect sealing of which is secured by ground glass surfaces coated with vaseline.

Between December 1, 1906, and the latter half of June, 1907, the clock ran for several short periods under such varying conditions that no results of value could be obtained therefrom. The clock was finally started, sealed, and the air pressure reduced to 560^{mm}, in the latter half of June, 1907. The

mean yearly pressure at Mt. Hamilton is about 650^{mm}, with a range of $\pm 13^{mm}$; so that 560^{mm}, being 90^{mm} less than normal, is safely below any possible outside pressure.

At present the clock is mounted in a small fireproof room fitted with double doors, in the basement of the Meridian Circle House. There is no other provision for constant temperature, and therefore the pressure varies within the glass case with variations of temperature. But since the effect of outside temperature is felt only gradually inside the case, the pressure varies in a correspondingly gradual and progressive way, never falling precipitously, as is the case outside just preceding a storm.

All the data gathered since the clock was completely fitted up and started, in June, 1907, has been carefully gone over, giving a full six months' uninterrupted rate. These rates were derived from observations for clock correction with the Meridian Circle, either in connection with some current programme or from especially prepared lists. Up to September 4th, Dent sidereal clock, numbered No. 4 in our series, was used for a standard, with which all the other sidereal as well as mean-time clocks were compared daily. During this period the rates derived for No. 5, the Riefler, were from corrections of either the same or but slightly later epochs. After September 4th, owing to an unsatisfactory fluctuation in the rate of No. 4, No. 5 was substituted, so that during the rest of the period its rates are derived directly from observations. Clock errors during the six months from June, 1907, to January, 1908, were derived from observations on an average of every six days, and, except for one interval of seventeen days, were quite uniformly distributed.

During the same interval the average temperature was $54^{\circ}.8$ F., with an average range of 3° for the intervals between which clock corrections were derived. The maximum for the period was $+64^{\circ}$ F., in August, 1907, and the minimum $+42^{\circ}$ F., in December, 1907. It would have been better, had a whole year of observations been available, for at present data can be used only during a period from maximum to minimum temperature. A complete year would also have given the reverse condition as temperature went from minimum to maximum again. During December, 1906, when the clock was first started, the thermometer went as low as

+ 35° F., giving a range of 29° for the year against 22° for the six months used. At that time, however, the clock was exposed more than usual, while being adjusted, and temperatures outside were unusually low, also.

A plot of the rate during this period, together with a plot of temperature and barometer range during the same period, show quite exact agreement. Whether this rate change is due directly to temperature effect on the pendulum, or indirectly through its effect on pressure, or to both, is as yet uncertain. It would be possible to test the direct effect of temperature, if the pressure were watched carefully, and kept constant by admitting more air or pumping out, as circumstances required.

However, it is possible to arrive at the variation in clock rate and barometric change concurrent with temperature variations. Readings of the thermometer are made to the nearest degree and of the barometer to the nearest millimeter. A least-square solution of the data gives $+1.3^{mm}$ as the change in barometer per degree Fahrenheit This, when applied to the barometric readings, gives an average residual of $\pm 0.73^{mm}$, which is about one ninth of the average residual for uncorrected readings of the barometer. CHARLES's law states that the pressure of a gas, of constant volume, varies directly as the absolute temperature. At the pressure here considered the variation of pressure per degree Fahrenheit amounts theoretically to $+1.1^{mm}$. This, taken in connection with an observed change of $+1.3^{mm}$ per degree Fahrenheit, shows that the sealing of the glass chamber is quite satisfactory.

The average rate for No. 5 for the period was $-0^s.165$ per day, with an average residual of $\pm 0^s.089$. The smallest was $0^s.00$, in August, 1907, at a temperature of $+61°.6$ F., and the largest $-0^s.37$, in December, 1907, at a temperature of $+42°.8$ F. From the plot, mentioned before, it was evident that a change of rate accompanied a change of temperature. A least-square solution for this variation gave $+0^s.016$ per degree Fahrenheit. When the rate is corrected for temperature, the average residual is $\pm 0^s.042$, as compared with $\pm 0^s.089$, the average residual for observed rates.

The rates for the two Höhwu sidereal clocks, numbered No 3 and No. 8 in our series, have been derived from comparisons with the standard sidereal clocks at epochs corresponding to

those used for the Riefler. During this period the residual from the mean rate was more than twice as large as usual, being $\pm 0^s.29$ and $\pm 0^s.32$ respectively. A change of rate of 1^s in that time was quite apparent in both clocks. When a change of rate of $+0^s.04$ for No. 3 and $-0^s.04$ for No. 8 per interval between which clock corrections were obtained, is applied to these rates, the average residuals are reduced to $\pm 0^s.14$ in both cases. Previous investigation has failed to connect changes in the rates of these clocks with temperature variations, and the fact that in the present instance the changes of rate of the two, while numerically the same, are of opposite signs, leads to the same conclusion. These clocks are mounted in the clock-room, with no particular protection from changes of temperature in the room.

Dent sidereal clock, until September 4, 1907, used almost exclusively for a standard upon which to base the others, has been recently investigated by Professor TUCKER in connection with some of his fundamental work. He is quoted as follows:

"The Dent clock is inclosed in a small chamber built into the clock room, and is protected by double doors from changes of temperature in the larger room. The daily change of temperature in the clock rarely amounts to more than one degree, and is usually progressive for periods of considerable length.

"The total variation in a year averages 34°, from 40° to 77° F. being the extreme range on record. During the periods of about one week, into which the tabulation of corrections is divided, the average change is less than 4°. The maximum falls in August, the minimum in December, and the mean temperatures occur in June and October. The yearly mean is close to 58°.

"The variation in the rate of the clock has a well established connection with the change in temperature, which has generally been reckoned at $+0^s.04$ for a rise in temperature of one degree. For a period of seven months, in 1907, March to September inclusive, the change of $+0^s.03$ has recently been derived, by least square solution. The application of this temperature correction to the rate results in reducing the average residual for the weekly intervals from $\pm 0^s.21$ to $\pm 0^s.11$, for the seven months. The clock retained a consistent rate during this period, which shows the Dent at perhaps

its best performance. Preceding and following this period, the rate of the clock made abrupt changes."

Taking into consideration this somewhat erratic action on the part of the Dent, and the highly satisfactory way in which the Riefler has been performing, its arrival was timely.

Thanks are due to Professor TUCKER for aid in preparing this note.

R. F. SANFORD.

MT HAMILTON, CAL, January 23, 1908.

THE ECLIPSE OF JANUARY 3, 1908.

Before this number of the *Publications* goes to press, I take pleasure in announcing that the total solar eclipse of January 3, 1908, was observed successfully by the Crocker Expedition from the Lick Observatory, University of California, and by the expedition of the Astrophysical Observatory, Smithsonian Institution The united expeditions were landed on Flint Island on December 9th by the U. S gunboat "Annapolis," in command of His Excellency C. B. T. MOORE, U. S. Navy, Governor of Tutuila. An observing site was selected in the midst of the cocoanut trees, and preparations proceeded rapidly, notwithstanding the tropical heat and the multitudes of showers. Every arrangement for securing the observations during totality was completed in good time.

The forenoon of January 3d was alternately clear and cloudy, with the clearness much in excess. About ten minutes before the eclipse was total, clouds formed rapidly, until the sky was densely covered. Just as the time-keeper called from his chronometer, "Five minutes before totality," a drenching rain fell, and all seemed lost save honor. At the end of two or three minutes the rainfall began to decrease and the clouds in the east gave signs of breaking Less than a minute before totality the slender crescent of the Sun showed faintly through the clouds, though a moderate rain was still falling. The rain and clouds grew rapidly lighter, and the last drops fell at two or three seconds after totality began Immediately after the beginning of totality the corona was faintly visible through the thin clouds These continued to disperse rapidly During the second quarter of the total phase the clouds were extremely thin, and during the third and fourth quarters the sky was essentially clear.

About ten seconds before totality, the rain having nearly ceased, the order was given to the workman seated on top of the outer of the two towers supporting the forty-foot camera to remove the tarpaulin from over the lens. The order was executed promptly and the remnant of the Sun's crescent was seen by the observer inside of the camera just one second before totality. The signal "Go!" was called by the observer at the instant when the crescent disappeared. Such of the instruments as were still covered, awaiting the end of the rain,—for example, the larger cœlostat,—were uncovered within a few seconds, and the programme of observations was thenceforth carried through without a single slip. The twenty instruments, driven by seven clocks, and the twelve observers did their work to perfection. Two spectrographic exposures planned for the twelve seconds immediately preceding totality were necessarily omitted, and some of the sensitive plates were damaged by getting wet in the downpour. The remaining exposures were expected to give good results; and such proved to be the case when the plates were developed, during the following two nights. All of the instruments were in perfect focus and adjustment.

The observing station of the Smithsonian Institution was located on the beach, for scientific reasons, about one fourth of a mile northwest of the Lick Observatory station. Here the rain was lighter and the sky cleared earlier, so that Director Abbott had an essentially clear sky during the whole of totality. His interesting programme was carried out to his complete satisfaction.

Immediately following the drying of the photographic negatives, they were packed with care and sealed in tin for shipment to Mt. Hamilton. The expeditions re-embarked on the U. S. gunboat "Annapolis" on January 5th, arrived in Tahiti on the 7th, and in San Francisco on the 25th.

All the members of the expeditions were entirely free from illness at Flint Island.

We received extensive assistance from many people, which it will be a pleasure to acknowledge in our first formal publication on the subject.

An English expedition, in the charge of F. K. McClean, Esq., was our near and agreeable neighbor from December 23d to January 3d. Mr. McClean's party sailed from Flint

Island about three hours after the eclipse occurred, the plan being to develop the photographs in the dark-room on his vessel. We hope that his photographs have been found to be excellent.

W. W. CAMPBELL.

GOLDEN GATE, January 25, 1908.

SOME TESTS OF THE VERTICAL CŒLOSTAT OR "TOWER" TELESCOPE OF THE MT. WILSON SOLAR OBSERVATORY.

The vertical cœlostat telescope described in *Contributions from the Solar Observatory*, No. 14, was erected on Mt. Wilson last summer, and has been in regular use since October. A 17-inch cœlostat, with mirror 12 inches thick, is mounted at the summit of a steel tower 65 feet in height. From the cœlostat the sunlight is reflected to a second mirror of elliptical form, which sends it vertically downward to a 12-inch visual objective of 60 feet focal length. The solar image is formed in a house at the base of the tower, where it is studied with a spectrograph of 30 feet focal length, standing in an underground chamber 8½ feet in diameter and 30 feet deep. A spectroheliograph, also of 30 feet focal length, is being constructed for use with this telescope, but at present a simple attachment to the spectrograph adapts it for the monochromatic photography of the Sun.

The 5-foot spectroheliograph, when used with the Snow telescope, yields excellent photographs of the calcium, hydrogen, and iron flocculi. For narrower lines, however, higher dispersion is required, which involves longer exposures. With the Snow telescope these cannot be given, on account of the change of figure of the mirrors in sunlight. There is not only a marked lengthening of the focus, but also a decided effect of astigmatism, due to the distortion of the two plane mirrors. The mirrors of the vertical cœlostat telescope (commonly known as the "tower" telescope) were made very thick in the hope of reducing this distortion.

This plan has succeeded admirably, though there is reason to believe that even better results would have been obtained if somewhat thinner glass disks had been used for the mirrors. The change of focus is so slow that an exposure of half an hour or more can be given with the spectroheliograph. Moreover, no effects of astigmatism have been noticed until after the telescope has been in continuous use for several hours.

It is a curious fact that with this telescope the focal length *shortens*, while with the Snow telescope it lengthens, on exposure to the Sun. This appears to be due to the fact that the broad edges of the very thick mirrors, when heated by the air, expand and render the front and rear surfaces of the mirrors concave.

In the morning, when the temperature of the air is rising, the slow change of focus continues, even when the mirrors are shielded from the Sun. In the afternoon, when the temperature is falling, continued exposure to the Sun fails to prevent a return of the figure to normal. These facts seem to favor the explanation suggested above.

It was hoped that the great elevation of the cœlostat above the heated ground, and the use of a vertical, rather than a horizontal beam, would prove advantageous. This expectation has also been realized. The definition always appears to be from one to two points (on a scale of ten) better than with the Snow telescope. In making the comparative tests care was taken to keep the mirrors of the Snow telescope covered until the simultaneous observations were made, and to cut down the aperture to twelve inches.

Spot spectra photographed with the 30-foot Littrow spectrograph by Mr. Adams and myself are much superior to those secured with the 18-foot Littrow spectrograph of the Snow telescope. As they are made in the third and fourth orders of a 4 inch grating (the one formerly used with the 18-foot spectrograph, and the only one available for the higher orders), the scale is great enough to permit measurements of high precision to be made. Some of the photographs already obtained are suitable for the definitive map of the sun spot spectrum, on the scale of Rowland, which will be issued as soon as a sufficient range of the spectrum has been covered.

Excellent photographs of the spectra of the limb and center of the Sun, and good preliminary results with the spectroheliograph, have also been obtained. The tower telescope appears to be a decided success, and will prove a most valuable supplement to the Snow telescope, which still possesses special advantages for certain classes of work.

George E. Hale.

Observations of Saturn's Rings in 1907[1]

Since July 23, 1907, the planet *Saturn* has been kept under observation as regularly as the weather, and the arrangement of the programme of work with the 36-inch telescope have permitted. Unfavorable weather conditions made it undesirable to examine the planet earlier in the year, and my observations will now be interrupted by absence from the observatory.

Though, according to the American ephemeris, the Sun did not pass through the plane of the rings until about 16^h, P. S. T., July 24th, the rings were seen as a very bright line[2] on the preceding morning, July 23d, 15^h, P. S. T., and have been visible whenever examined since that date. As seen in projection on the planet on July 23d and 24th, the line was estimated to be about $0''.2$ broad, the estimate being based on comparisons with the micrometer thread (thickness $0''.10$), placed parallel to it.

On October 4th, the date assigned for the passage of the Earth through the plane of the rings, they appeared as an exceedingly faint line of light on either side of the planet, which, under the very poor observing conditions, was difficult to trace. At the steadiest moments, comparison with the micrometer thread showed that its thickness certainly did not exceed $0''.10$, and was probably not more than $0''.07$. From the appearance of the rings at this date and subsequently, I infer that the Sun had already passed through the ring-plane on July 23d, for they were then certainly broader and much brighter than in October.

No very unusual phenomena were detected until Saturday, October 19th. When I entered the dome on that night, Mr. Wright, who had directed the telescope upon *Saturn* for the benefit of the Saturday-night visitors, called my attention to two bright points or knots in the line of the rings, on either side of the planet. My measures, made a little later, showed these points to be nearly symmetrically placed with respect to the planet, the two preceding ones being a little further out than the corresponding points on the following side. They were so sharp that they might easily be mistaken for satellites.

It is certain that they were not visible on October 12th, for the seeing on that night was good, and the ring was examined with special care to note the effect upon it of the presence of

[1] Abstract from *L. O. Bulletin* No. 127.

[2] It was bright enough to be readily visible even in the 12-inch telescope.

Mimas and *Enceladus*. These satellites were practically tangent to the ring, the former on the north edge, very near the preceding extremity, the latter on the south, 2″ or 3″ in from the following extremity.

Unfortunately, the weather prevented further measures until October 31st, though on October 24th the knots were distinctly seen in a transitory break in the clouds that hid the planet. The measures on October 31st, and later dates, place the knots farther from the planet than did those made on October 19th. This increase in distance may be real, though no certain motion has been observed since October 31st, unless, perhaps, in the second knot on the preceding side.

On November 1st, a third knot appeared very near the planet's limb, on either side, but, unfortunately, a dense dripping fog covered the mountain before even one complete set of measures could be secured. These knots were invisible on the preceding night, though the ring, both then and on October 19th, was brighter in this part than farther out.

Measures made on eight nights, between October 10th and November 12th, give the following results for the distances of the knots from the nearer limb of the planet:—

Prec. 3	Prec. 2	Prec. 1	Fol. 1	Fol. 2	Fol. 3
8″.38	3″.47	1″.55	1″.39	2″.84	8″.00

I have had several excellent opportunities to compare the appearance of these knots with the inner satellites when near the extremity of the ring or tangent to its edge. From notes made at these times, I should describe them as being nearly as sharp as small satellites, and as presenting quite closely the appearance of *Enceladus* when it is nearly tangent to the ring. In fact, on October 8th, when *Enceladus* reappeared after eclipse, just north of the ring and near the inner knots, it was for a few moments mistaken for a *new knot*. The two inner knots on the following side are considerably brighter than the others, and sensibly brighter than *Enceladus*. Even the faintest of the knots are decidedly brighter than *Mimas*, which I have not been able to follow closer than 4″ from the planet's limb. There has been no marked change in brightness, except in the inner knot on the preceding side. Since November 8th it has appeared equal to No. 2 on the same side, and to the two outer knots (No. 3), while on November 1st and 2d it was decidedly fainter.

The bright line is not of uniform brightness through its whole extent, the portion between knots 1 and 2 (numbered in order of increasing distance from the planet) being always by far the brightest, while the extremity became exceedingly faint 2″ to 3″ beyond knot 3. This relation holds true for both the preceding and the following sides, but the following side, as a whole, appears to be brighter than the preceding, no doubt because of the brightness of knots 1 and 2 on the former side. On the preceding side, the bright line was usually visible right up to the planet's limb, while on the following side it was usually lost at about 0″.5 from the limb. At all times since October 4th the bright line on either side, near the limb, has been as broad as the adjacent extremities of the part in projection on the planet, and the three portions have been segments of the same straight line. The curvature of the projected portion is hardly sensible. It may also be noted that this portion did not, at any time since July 23d, appear *black*, nor as dark as the illuminated micrometer thread placed beside it. A dark gray, that might be called a half-tone, would best describe its appearance.

When the seeing was poor, the ring would often apparently show gaps; but these always disappeared in the steadier moments, and the line could be seen continuously through its whole extent, except the 0″.5 adjoining the following limb of the planet. When one of the satellites, except *Mimas*, was on the edge of the ring, the line on either side of it was generally invisible, but reappeared as the satellite moved. So far as my observations go, therefore, there has been no gap in the line of the ring.

All of the knots appear to be tangent to the south edge of the line, hence it may be inferred that they are due to irregularities on the illuminated surface of the rings. As the rings are known to be revolving very rapidly, and my measures show no appreciable motion, it is also evident that they are due to causes extending entirely around the ring system. But any more definite explanation is very difficult, the more so from the fact that the inner pair fall well inside of the dark ring, the middle pair about at the extremities of the inner diameter of this ring, and the outer pair on the inner bright ring.

The only reference I can find to similar appearances in earlier years is BARNARD'S[1] note on the lumps on the south edge of ring, on the following side, seen on October 29, 1891. He assumed that they were two of the inner satellites. I have looked up the positions of all the known satellites for that date, and find that not one of them was at all near the lumps, so that unquestionably these were of the same nature as the present appearance.

It is almost unnecessary to add that every precaution has been taken to avoid deception in making these observations. The ring has been examined with different eyepieces, with planet occulted, and with occulting bar removed. Under moderately good conditions it was always easily seen, and the knots were very distinct. Especially have I been careful to convince myself that I was not dealing with such an optical phenomenon as is described by BARNARD.[1] The ring, as seen now, is not an effect of contrasts.

R. G. AITKEN.

[NOTE (added February, 1908). Professor TUCKER continued these observations after November 12th, and has published the measures of two nights in the Bulletin containing my own. On these dates the inner knot on either side was not visible. He also calls attention to observations of similar phenomena[2] by W. C. BOND, at Harvard, in 1848. It may be proper to state here that I did not attempt to look up original articles on *Saturn* of earlier date than 1892, relying upon several standard discussions of *Saturn* and his system for references to earlier observations. No reference to such irregularities in the ring appears in the works which were consulted. Readers who are interested in the subject are referred to BOND's original paper in *Harvard Observatory Annals*, Volume II, Part I. BOND's explanation is simple, and may be adequate so far as the two outer knots are concerned, but apparently it fails to account for the innermost ones. Mr. W. H. WRIGHT suggests that these are due to the attenuated meteoric constitution of the crepe ring.—R. G. A.]

[1] *Monthly Notices R. A. S.*, 52, 421.

[2] An important difference, as Professor TUCKER points out, is that BOND makes the knots perfectly symmetrical with respect to the planet, while the present series of measures places the following ones closer.

GENERAL NOTES.

Second Catalogue of Variable Stars.—In 1903 a provisional catalogue of variable stars was published by Harvard College Observatory as No. 3 of Volume XLVIII of the Annals of that institution. During 1907 a second catalogue (the word "provisional" is omitted) was published as Part I of Volume LV. Both catalogues were compiled by Miss ANNIE J. CANNON, assistant in the observatory, under the supervision of Director PICKERING.

The provisional catalogue contained 713 stars, while the one just issued contains 1,447 stars, which, however, does not include 514 variables in globular clusters, and 1,791 very faint variables in the Magellanic Clouds, found by photographic methods. If these be added to the total of the catalogue, the grand total is 3,748, 2,909 of which were discovered at the Harvard College observatories.

The number of known variable stars has grown wonderfully during the last half century. The first catalogue published was by ARGELANDER, in 1844, and it contained reference to eighteen variables. SCHÖNFELD'S first catalogue, 1865, contains 113 stars; CHANDLER'S first catalogue, 1888, 225 stars; CHANDLER'S third catalogue, 1896, 393 stars; Harvard provisional catalogue, 1903, 783 stars; Harvard second catalogue, 1907, 1,447 stars.

The observation of variable stars has lagged far behind discovery, and a glance at this new catalogue shows how deficient our knowledge of many of these interesting objects is. The catalogue gives the classification of the variables according to the plan suggested by Professor PICKERING in 1880. Of the first class (new stars) there are now 20; of the second class (long period variables), 434; of the third class (irregular variables), 134; of the fourth class (short-period variables of continuous variation), 77; of the fifth class (*Algol* type variables), 47; of class unknown, 735. It is thus seen that the class of over half the variables listed is unknown. Many of these are the faint variables recently discovered by Professor WOLF and the Harvard observers in nebulous regions.

S. D. T.

Allegheny Observatory.—Number 1 of Volume I, *Publications of the Allegheny Observatory,* has recently appeared. It is a six-page contribution on the distortion of photographic films, by Dr. FRANK SCHLESINGER, director of the observatory. In this investigation Dr. SCHLESINGER used methods which differ materially from those employed by previous investigators. A Cramer instantaneous isochromatic plate was exposed to the region about 61 *Cygni,* and then developed, fixed, washed, and dried by the ordinary process. The positions of fifty-nine stars were determined by means of a measuring engine, and then the plate was again subjected to a process of developing, fixing, washing, and drying, and again measured under circumstances as nearly as possible identical with those used in the first instance. The distortions found in this way were all small, much smaller than the errors of bisection for good star images.

The plate was then subjected to nine excursions through the processes of development and drying, and measured for the third time, but the magnitude of the distortions was not increased. A number of variations in the experiments were introduced, but the resulting distortions were in all cases small.

Some Astronomical Consequences of the Pressure of Light.—Regarding a beam of light as a momentum carrier, it is easily seen that if the receiving surface has velocity u towards the source and the velocity of light is U, the pressure is increased by the motion by the fraction u/U. If the velocity is reversed, the pressure is decreased by this fraction. This is the "Doppler reception effect."

If the source is moving, and we assume that the amplitude of the emitted waves depends on the temperature and nature of the source alone, it can be shown that the pressure on the source is $U/(U \mp u)$ of its value when the source is at rest. This is the "Doppler emission effect."

In considering the consequences of light-pressure, it is necessary to know the temperature of a body exposed to the Sun's radiation. It can be shown that a small black particle, at the distance of the Earth from the Sun, has about the mean temperature of the Earth's surface,—say, 300° Abs.,—and that the temperature of the Sun is about twenty times as high,—

say, 6,000° Abs. The temperature of the particle varies inversely as the square root of its distance from the Sun.

The direct pressure of sunlight is virtually a lessening of the Sun's gravitation-pull. On bodies of large size this is negligible. On the Earth it is only about a forty-billionth of the Sun's pull; but the ratio increases as the diameter decreases, and a particle one forty-billionth of the Earth's diameter, and of the same density, would be pushed back as much as it is pulled in, if the law held good down to such a size. If the radiating body is diminished, the ratio of gravitation-pull to light-push is similarly diminished, and it can be shown that two bodies of the temperature of the Earth's surface and the Earth's mean density would neither attract nor repel each other, if their diameter was about one inch. The consequence of this on a swarm of meteorites is obvious It is probable that this balancing of gravitation and light pressure must be taken into account in the motion of the particles supposed to constitute *Saturn's* rings.

When we consider the motion of a small particle round the Sun, we have, first, the direct pressure lessening gravitation. If it has density equal to that of the Earth and diameter one thousandth of an inch, the lessened pull at the distance of the Earth will imply a lengthening of the year by nearly two days Secondly, the Doppler emission effect comes into play; for the particle crowds forward on its own waves emitted in front, and draws away from those emitted behind, so that there is increase of pressure in front and a decrease behind. Thus there is a force resisting the motion The particle will then tend to fall inwards in its orbit, and, in the case considered, about 800 miles in the first year. It would probably move in a spiral into the Sun, and reach it in less than one hundred thousand years. A particle one inch in diameter would reach the Sun from the Earth in less than one hundred million years.

The Doppler reception effect will not come into play in a circular orbit, but in an elliptic orbit it acts as if it were a force resisting change of distance, and therefore it tends to make an elliptic orbit even more circular.

Applying these considerations to a comet regarded as a swarm of small particles coming into our system, a sorting action will at once begin. The smaller particles will have their

period of revolution lengthened out more than the larger ones, and they will tend to trail behind. The Doppler emission effect will damp down the motion, and again more markedly with the smaller particles, and all will tend to spiral into the Sun The Doppler reception effect will tend to destroy the ellipticity of the orbit, more especially with the smaller particles, and ultimately the particles of different sizes may move in orbits so different that they may not appear to belong to the same system. In course of time they should all end in the Sun Perhaps the zodiacal light is due to the dust of long-dead comets.

It appears just possible that *Saturn's* rings may be cometary matter which the planet has captured, and on which these actions have been at play for so long that the orbits have become circular.—*Extract from an article by* J. H POYNTING, *in Popular Astronomy for December.*

Periodic Comets Due in 1908.—Comet Giacobini, 1900 III, period about seven years, and Comet Denning, 1881 V, period about 8.8 years, are expected early in the year. ENCKE's comet, first seen in 1786 by MÉCHAIN, and observed at every return since 1818, when its period was found by ENCKE to be about 3.3 years, is due to return to perihelion at the end of April. Comet 1869 III, of period about 5.5 years, discovered by TEMPLE, and found to be periodic after SWIFT rediscovered it in 1880, has been observed since only at the apparition of 1891; it is expected in the summer.

Notes on the Transit of Mercury, 1907, November 14th, from Continental Observations.—Observed times of contact seem to have been about a minute earlier than computed times The black ligament was conspicuous. The planet appeared very black Little evidence was obtained of the presence of its rare atmosphere.

Meteorites.—The *Journal B. A. A.*, Volume XVIII, No. 2, gives notes from an abstract in *Nature*, by L. J. S., of "Some

Recent Papers on Meteorites." Dr. H. A. WARD, in *Proceedings of the Rochester Academy of Science*, Volume IV, pages 137-148, 1904, describes the Willamette meteorite, found in 1902 near Willamette, Oregon. The mass of metallic iron measures 10 x 6½ x 4¼ feet, and weighs about 15½ tons, being the third largest meteorite known. The two heavier ones are the Anighito, of 36½ tons, brought by PEARY from Greenland, and the Bacubirito (Mexico), with an estimated weight of 27½ tons. The Willamette meteorite is conical in form, and was found embedded in the ground, base uppermost. It is probable that in consequence of weathering none of the original surface remains. Analysis shows 91.5 per cent of iron, 8 per cent of nickel, and small amounts of cobalt and phosphorous. Professor O. C. FARRINGTON, in *Field Columbian Museum Geol. Ser.*, Vol. III, pp. 57-110, 1907, collects 360 published analyses of 248 meteoric irons. The average composition is: Iron, 90; nickel, 9; cobalt, 0.9; copper, 0.02 per cent.

Notes from "Science."—The Lalande prize of the Paris Academy has been awarded to Mr. THOMAS LEWIS, of the Royal Observatory, Greenwich, and secretary of the Royal Astronomical Society. *The Observatory* states that during the last twenty years there have been twenty-one recipients of this prize, of whom nine were American, nine French, one South American, one Italian, and (the present award) one Englishman.

Dr. WALTER M. MITCHELL has been appointed director of the Haverford College Observatory.

PIERRE CHARLES CESAR JANSSEN, director of the Meudon Astrophysical Observatory, died on December 23d, at the age of eighty-three years.

M. GONNESSIAT, of the Paris Observatory, has been appointed director of the Observatory of Algiers.

Dr. E. O. LOVETT, professor of mathematics at Princeton University from 1900 to 1905, and since professor of astronomy, has resigned to accept the presidency of the institute established at Houston, Texas, by the late WILLIAM M. RICE, with an endowment, which, after long litigation, is said still to amount to over two million dollars.

M. BOURGET, of the Toulouse Observatory, has been appointed director of the Marseilles Observatory, to succeed M. STEPHEN, who has retired.

M. M. NYRÉN, of the Pulkova Observatory, retired from his office at the end of 1907.

Charles A. Young.—On January 3d America lost another of her eminent astronomers through the death of Professor C. A. YOUNG, at Hanover, N. H., to which place he retired after becoming professor *emeritus* of astronomy at Princeton University in 1905. An appreciative article on the life and work of Professor YOUNG was published by Director E. B. FROST, in *Science* for January 24th, and it was from this article that most of the information given below was obtained.

"CHARLES AUGUSTUS YOUNG was born on December 15, 1834, at Hanover, where his grandfather and father successively occupied the chair of natural philosophy in Dartmouth College during the period from 1810 to 1858. He entered college early, and graduated with distinction in 1853 as bachelor of arts. During his student days he assisted his father in astronomical observations, and accompanied him in 1853 on a trip to Europe to purchase instruments for the Shattuck Observatory, then in the course of erection. For two years after graduation he taught classics at Philips Academy, pursuing at the same time theological studies at the Andover Seminary. In 1857 he went to Hudson, Ohio, as professor of mathematics and natural philosophy at Western Reserve. During several summer vacations he assisted in the governmental survey of the Great Lakes. Responding to the call of patriotism in 1862, he was for four months captain of Company B in the Eighty-fifth Regiment of Ohio Volunteers, which was largely recruited from students.

"In 1866 he returned to Dartmouth as professor of natural philosophy and astronomy, thus continuing the family tradition. . . . In 1877 he accepted a call to Princeton, where much larger instrumental facilities were offered to him, with less confining teaching duties. He gave, however, much time to the organization and equipment of the Students' Observatory, making it then probably the best in the country. A powerful spectroscope was provided for the 23-inch equatorial of the Halsted Observatory, and with this he made important observations of the chromosphere and sun-spots."

Professor YOUNG was especially interested in the physical side of astronomy, and was one of the pioneers in the use of the spectroscope, especially in its application to the study of the Sun. He observed the solar eclipse of 1869 at Burlington, Iowa, and demonstrated from his observations the gaseous nature of the corona; that of 1870, in Spain, when the flash spectrum was seen for the first time; that of 1878, at Denver; and that of 1900, in North Carolina. He also made a trip to Russia in 1887 to observe the eclipse of that year, but clouds intervened. In 1872 he spent the summer in Wyoming, at an altitude of 8,000 feet, for the purpose of measuring the wave lengths of lines of the solar spectrum, which could not be successfully observed at lower altitudes with the instrumental equipment then available. In 1874 he observed the transit of *Venus* at Peking. Professor YOUNG'S excellent book, "The Sun," first issued in 1881, and last revised in 1895, has been translated into several languages.

Professor YOUNG'S text books, "General Astronomy," "Manual of Astronomy," "Elements of Astronomy," and "Lessons in Astronomy," constitute the most popular and successful series of text-books on astronomy ever issued, and have been used by over a hundred thousand students. Professor YOUNG was very successful as a teacher, and belonged to that class of men who are the most useful in the American university of to-day,—eminent investigators who are also successful teachers.

S. D. T.

Head of Southern Observatory.—The superintendence of the work at the proposed Southern Observatory of the Carnegie Institution has been offered to Astronomer R. H. TUCKER, of the Lick Observatory, at present in acting charge of the latter, during the absence of the director.

The plan of observing is the design of LEWIS BOSS, director of the Dudley Observatory at Albany, who has been engaged for many years in the observation and reduction of a large and accurate fundamental catalogue of stars. The work of the Southern Observatory will include the stars that are too far south to be measured at the observatories of the northern hemisphere. It is expected that three years will be required for the plan, and the Southern station will be located either in New Zealand, South America, or South Africa. The party will

probably consist of seven observers, several of whom have already been engaged.

The selection of one of the Lick Observatory staff for the prosecution of this work is one of the instances of the recognition of the standing of this institution in professional work that have not been uncommon of late. The requirements of this particular plan are mainly those of experience, technical skill, and persistence in the execution of a scheme of work. The work of a large observatory is very much specialized, just as professional work has developed in other lines.

It was as an observer, specially trained, that Mr. TUCKER was invited, fifteen years ago, to join the Lick Observatory force, and to take charge of the Meridian Circle and its work. Three quarto volumes have been since published, entirely devoted to the results of the observations made with this instrument during this period at the Lick Observatory. The work is of the character that has been fundamental in the development of our knowledge of the universe of stars and in tracing the motions of the planets of our complex solar system. The larger observatories in all parts of the world have always a force of astronomers working along this line. The smaller observatories rarely do any of this class of work.

This present expedition suggests, in a way, the early trip of Lieutenant GILLISS to Chile, to observe the Southern stars; and the much more extensive and successful scheme of Dr. B. A. GOULD, both of which eventually resulted in the foundation of national observatories at Santiago, Chile, and at Cordoba, Argentine Republic, respectively. There were earlier expeditions to the Cape of Good Hope, the first of LA CAILLE, and, later, one of HERSCHEL, which led to the establishment of the Royal Observatory at Capetown, now one of the finest in the world. The present scheme is expeditionary only, and the equipment will be brought back to this country when the specific work is completed.

The large Pistor and Martins Meridian Circle, of the Dudley Observatory, will be used for the Southern plan, and it introduces some feeling of sentiment, from the fact that the first professional observations of the astronomer, who is to take charge of this work, were made with that instrument.

Should San Luis, in the Argentine Republic, be finally selected as the observing station, there would be additional

fitness in the working out of the scheme, since it was from the National Observatory at Cordoba, two hundred miles distant, that the observer came here, fresh from nine years' service under the Southern skies.

The Mills Expedition, of the Lick Observatory, is now located at Santiago, under the charge of Dr. H. D. CURTIS; and while the Cordillera of the Andes would lie between the two stations, making a barrier of no ordinary magnitude, the two stations might easily get into touch with each other, by exchange of compliments. The work of the two stations does not conflict in any way; the established one is for the physical investigation of Southern stars, by means of the spectroscope; the new one will confine its work to the measurement of the positions of the stars.—*San Jose Mercury, January 24th.*

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MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN ROOM 601 MERCHANTS EXCHANGE BUILDING, SAN FRANCISCO, ON SATURDAY, NOVEMBER 30, 1907.

At the meeting of November 30, 1907, (the minutes with this exception have been published in No. 117 of these *Publications*) the Bruce Gold Medal for the year 1908 was awarded to Professor EDWARD C. PICKERING, Director of Harvard College Observatory. The following certificate of bestowal was signed by all Directors present:—

SEVENTH AWARD OF THE BRUCE MEDAL.

SAN FRANCISCO, CAL., November 30, 1907.

We, the undersigned, Directors of the Astronomical Society of the Pacific, hereby certify that, in accordance with the Statutes for the Bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day at 2 o'clock P.M., for the purpose of awarding the medal for the year 1908 and that, the provisions of the statutes relating to its bestowal having been complied with, the medal was awarded to EDWARD C. PICKERING, for distinguished services to astronomy, by the consenting votes of ten Directors.

Signed: R. G. AITKEN,* A. H. BABCOCK,* CHARLES BURCKHALTER, W. W. CAMPBELL,* R. T. CRAWFORD, CHARLES S. CUSHING, GEO. E. HALE,* DANIEL S. RICHARDSON, S. D. TOWNLEY, F. R. ZIEL.

* By proxy.

In answer to a letter addressed to Professor PICKERING, notifying him of the action of the Directors, the following letter of acceptance was received:—

CAMBRIDGE, MASS., January 8, 1908.

MY DEAR SIR:—

Your letter of January 1st, announcing that the Bruce Medal for the year 1908 has been awarded to me, has been received. Please convey to the Board of Directors of the Astronomical Society of the Pacific my great appreciation of the distinguished honor thus conferred upon me. It affords me great pleasure to have my name thus associated with that of Miss BRUCE and those of the eminent astronomers to whom the medal has already been awarded.

Yours very sincerely, EDWARD C. PICKERING.

DR. RUSSELL TRACY CRAWFORD,
Secretary Astronomical Society of the Pacific,
Berkeley, California.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE CHABOT OBSERVATORY, OAKLAND, CAL., ON JANUARY 25, 1908, AT 8 P.M.

A quorum was present. President CUSHING presided. The minutes of the meeting of November 30, 1907, were approved.

The Secretary reported that he had notified Director E. C. PICKERING, of Harvard College Observatory, that the Directors of this Society had awarded him the Bruce Gold Medal for the year 1908, and that Professor PICKERING had accepted the medal.

The following were elected to membership:

Miss Alice Joy	2521 Piedmont Avenue, Berkeley, Cal.
Miss Elizabeth E. Garvey	2440 Hillside Avenue, Berkeley, Cal.
Mr. W. F. Meyer	Students' Observatory, Berkeley, Cal.

The President was authorized to appoint an Auditing Committee of three members, and a Nominating Committee of five members.

It was moved, seconded, and carried that the Library of Stanford University be given Volume XV of the Society's *Publications* to replace their original volume, which was lost in the fire of April, 1906.

It was moved, seconded, and carried that the following be the schedule of prices for single copies of the *Publications*:—

One dollar for non-members.
Seventy-five cents for dealers.
Fifty cents for members.

The Secretary was instructed to place $500 insurance upon the Society's property.

A letter from Professor W. Steadman Aldis, offering some additional books for our Library, was read. The Secretary was instructed to convey the thanks of the Society to Professor Aldis, and to select from the list sent those books deemed useful to the Society.

Adjourned.

Minutes of the Meeting of the Society, Held in Chabot Observatory, Oakland, Cal., on January 25, 1908, at 8:30 p.m.

President Cushing presided. Upon calling the Society to order he announced that the meeting would be devoted to informal discussion of current astronomical problems.

The Secretary read Professor Pickering's letter accepting the Bruce Gold Medal, which had been awarded to him for the year 1908.

Professor Crawford made a few remarks upon the "Supposed Disappearance of *Saturn's* Rings." Later in the evening Professor Aitken made some remarks upon this same subject, and also gave a short talk upon his observations of the "knots" on *Saturn's* ring.

Professors Perrine and Aitken, who had just arrived from the eclipse expedition to Flint Island, gave some very interesting accounts of their experiences.

Professor Aitken read a short preliminary paper upon the eclipse, prepared by Director Campbell. The paper was dated from the Golden Gate.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr Chas. S. Cushing . . . . *President*
Mr A. H. Babcock . . . . *First Vice President*
Mr. W. W. Campbell . . . . *Second Vice President*
Mr. Geo. E. Hale . . . . *Third Vice President*
Mr. R. T. Crawford (Students' Observatory, Berkeley) . . . . . *Secretary*
Mr R. G. Aitken (Mount Hamilton, Cal.) . . . . *Secretary*
Mr F. R. Ziel . . . . *Treasurer*

Board of Directors—Messrs Aitken, Babcock, Burckhalter, Campbell, Crocker, Crawford, Cushing, Hale, Richardson, Townley, Ziel.

Finance Committee—Messrs Richardson, Crocker, Burckhalter.

Committee on Publication—Messrs. Aitken, Townley, Maddrill.

Library Committee—Messrs Crawford, Irving, Townley.

Committee on the Comet Medal—Messrs. Campbell (ex officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper 40 cents, of note paper, 25 cents, a package of envelopes 25 cents. These prices include postage and should be remitted by money order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco, California. Subscription price $5.00 per year.

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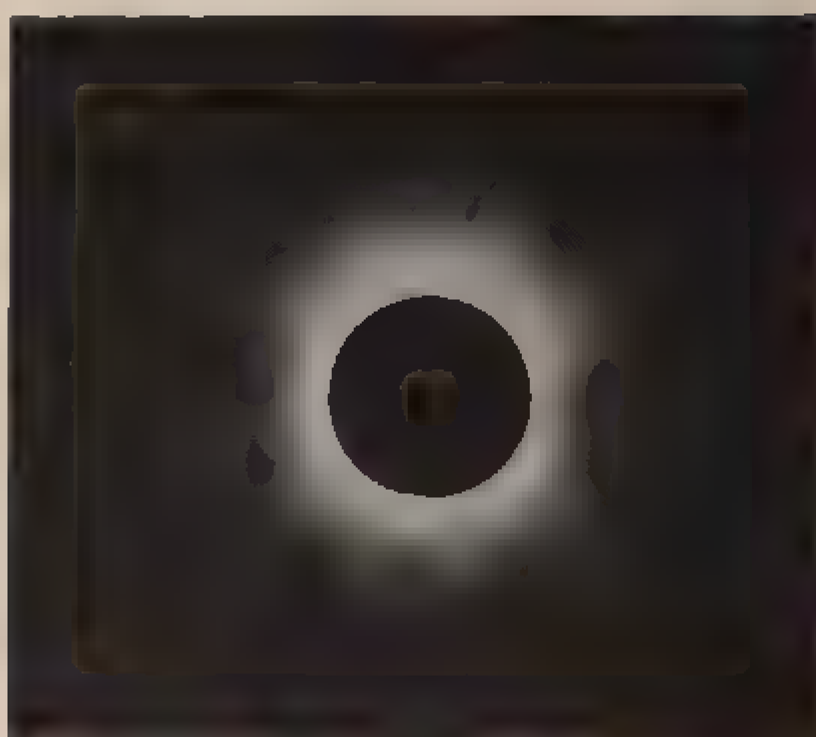

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THE SOLAR CORONA
January 3, 1908

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XX. San Francisco, California, April 10, 1908. No. 119.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO EDWARD C. PICKERING.

By Charles S. Cushing.

At the Twentieth Annual Meeting of our Society it becomes my duty as your retiring President to make a brief statement as to the progress and condition of the Society, and to announce the seventh award of the Bruce Gold Medal.

The total eclipse of the Sun in January, 1889, was the occasion of bringing together in this State many people interested in astronomical science. As a result of that meeting, the Astronomical Society of the Pacific was formed, and those connected with it have every reason to be proud of its progress since the foundation.

California is a land of sunshine and clear skies, and as astronomy appeals largely to the imagination, it is natural that the attention of some of the adventurous spirits who came to our shores during early days was here turned towards the skies. Like conditions bring about like results, and it is as natural for the inhabitants of California to take a continued interest in astronomy as it was for the ancient Chaldean shepherds to begin their observations under climatic conditions so closely resembling our own.

The writer has at times observed among magazine writers and critics a disposition to question whether, in many of the sciences, there has been and is being as much solid work done in the United States as in some of the older and more thickly settled communities of the Old World. All the writers, however, in these discussions except astronomical science from consideration, as it is conceded by all that in the development

of this particular science the United States cannot at least be regarded as occupying a secondary place.

In the development of this particular science California has taken a leading part, and I believe it can be said without exaggeration that there is no country in which more has been done, relatively, to establish observatories, to make and carry on useful investigations, and, generally, to cultivate and stimulate the science of astronomy. The contributions to this end, both public and private, have been most remarkable. Donations have been received from those of great and those of slender means to assist in this work.

The establishment of the great Lick Observatory by a pioneer of our State was one of the greatest contributions to modern science. It is probable that no one act has contributed more to the development of astronomical science than this. It has set an example for others to emulate, both within and without the State. It has brought generous contributions, both public and private, to astronomical science. It has brought together a number of scientists, who have contributed largely to scientific knowledge and who are continuing to reflect great credit on the institution so established.

The generosity of one citizen, a member of this Society, has enabled the Lick Observatory to establish and maintain a well-equipped station in the southern hemisphere, from which important results have been attained The generosity of another, also a member of our Society, has enabled the same observatory to conduct observations of total eclipses of the Sun on many different occasions and necessarily at widely scattered places. These observations have given it opportunities which have probably been unequaled by any other observatory.

It was the existence of the Lick Observatory which brought among us the men whose presence was necessary for the establishment of this Society The success of this Society has been remarkable, and I have only to point to the numerous applications from observatories throughout the world for its publications to show the esteem in which its efforts are held.

While the interest of the writer in astronomical science is that of an amateur only, whose time is almost wholly engrossed in other vocations, no one knows better than I do the debt which I desire now to publicly acknowledge, which the Society

owes to the little band of astronomers of the Lick Observatory. These members of our Society have with the most untiring industry contributed to and assisted in editing its publications over the entire period of its existence. They have lectured for us and have in many ways otherwise contributed to the success of the Society. Above all, they have extended to the members of the Society the privilege of meeting at the Lick Observatory and of seeing the practical workings of that great institution, a privilege the equal of which probably no other like society can enjoy.

Our Society now possesses an endowment of nearly twenty thousand dollars. The income from a considerable portion of this is being devoted towards our *Publications*. At the time of the great fire in San Francisco, of April 18, 1906, the Society had a very considerable library, which it maintained in its rooms in the building of the California Academy of Sciences. While in the destruction of this library the Society suffered severely, the generosity of various members and societies has done much to repair this loss.

I take pleasure in announcing that the library of the Society now consists of about two hundred and eighty-five bound volumes and about seven hundred pamphlets. Among the many contributions to the rehabilitation of our library I desire to refer particularly to that of Professor W. STEADMAN ALDIS, F. R. A S., of Oxford, England, who contributed fifty volumes, many of which are rare, and all of which are valuable; and to that of Professor EDWARD S. HOLDEN, who has sent a valuable contribution of books and pamphlets. Nearly all of the large observatories, including the observatory at Greenwich, United States Naval Observatory at Washington, and the Lick Observatory, have sent either complete sets of their own publications or sets as nearly complete as they could spare. In specially mentioning the foregoing contributions I have not forgotten the many other generous gifts to our Society. By the courtesy of the President of the University of California these books are housed at the Students' Observatory at that institution. The rapid rebuilding of San Francisco brings to mind the desirability of obtaining for the Society permanent rooms in San Francisco, where the library can be maintained and made accessible to those desiring to use it.

Among the funds of our Society is one contributed by the late CATHERINE WOLFE BRUCE, of New York, to be used for the purchase of a gold medal to be awarded, regardless of race or sex, for distinguished services to astronomy. By the terms of the trust creating this fund the medalist is chosen by the Board of Directors of the Society from persons nominated by six of the most prominent observatories of the world—viz.: Berlin, Harvard, Greenwich, Lick, Paris, and Yerkes.

This medal has been awarded in the past successively to Professor SIMON NEWCOMB, Professor ARTHUR AUWERS, Sir DAVID GILL, Professor GIOVANNI VIRGINIO SCHIAPARELLI, Sir WILLIAM HUGGINS, and Professor HERMANN CARL VOGEL. It now becomes my pleasure to announce the seventh award of this medal to Professor EDWARD C. PICKERING, Director of the Harvard College Observatory.

While the name of Professor PICKERING and his connection with Harvard College is so well known to all who take any interest in astronomy, it will not be out of place to here refer briefly to his career and to some of his many achievements.

EDWARD C. PICKERING was born in Boston, July 19, 1846. He graduated at Harvard College in 1865, and acted as a teacher of physics at the Massachusetts Institute of Technology for a period of ten years. Professor PICKERING's advent into astronomy came in the year 1877, when he became Director of the Harvard College Observatory. Prior to that time he had been more of a physicist and mathematician than an astronomer. At about the time Professor PICKERING became Director of Harvard Observatory, the rapid development of stellar photography and of stellar spectrum analysis emphasized the importance of the department of astrophysics. It is much to the credit of those who selected our medalist for the important position, which he has so long occupied, that they so early recognized the fact that the new director must be a chemist and a physicist.

During the nineteenth century scientific development along almost every line has been very rapid, and in no science is this more marked than in astronomy. The great development of photography and spectroscopy brought greater demands on the intelligence of the astronomer along lines which during the early part of the nineteenth century were hardly dreamed of. Professor PICKERING did not hesitate to start in imme-

diately after his advent into his new position to undertake works of vast magnitude, and in carrying his plans into effect he has shown the most unbounded energy, as well as unusual executive ability.

In his first annual report he announced his intention of undertaking the extensive work of reducing Argelander's comparative observations of variable stars, by measuring the brightness of the comparison stars, and thus determining the true brightness of the variables as given in the "Bonn Observations." This work he published some years later. The first paper on the subject was published in 1880, wherein, from mathematical reasoning, he proves that the variability of stars of the *Algol* type is due to a non-luminous body revolving around the star; the results he obtained from the ratio of the diameters of *Algol* and its satellite are very closely accordant with those announced by VOGEL some years later.

Professor PICKERING'S name will always be associated with the work carried on under the name of the Henry Draper Memorial. Professor HENRY DRAPER was a distinguished scientist, who was especially noted for his labors in celestial photography. In the year 1886 his widow made a liberal provision for carrying on researches in stellar spectroscopy as a memorial to her late husband. It is natural that the work proposed by her was along lines of investigation in fields which her husband had hoped to explore.

The trust was placed in the hands of Professor PICKERING, who was thus enabled to work with sufficient means to carry the task into execution. The investigations were planned to cover the entire sky, and involved an investigation into the conditions and physical properties of the stars as revealed by their spectra; and as the scheme was developed four telescopes were established for the observations, two at Cambridge and two at Arequipa, Peru. This work has been prosecuted to the present time with amazing industry.

Under the direction of Professor PICKERING, since its establishment, the Henry Draper Memorial has developed several new and unique lines of work. The objective prism and doublet have been substituted for the slit spectroscope and single lens, and by this means the spectra of a large number of stars are photographed simultaneously instead of singly by the former method. These photographs have been repeated until every

portion of the sky has been covered. By this method a photograph of the spectrum of every star in the sky permanently brighter than the ninth or tenth magnitude, besides many thousand that are fainter, has been obtained. These plates have been carefully examined, and as a result a large number of objects having peculiar spectra have been discovered.

To illustrate one of the results of this work it may be interesting to state that of eight novæ which are known to have appeared during the sixteen years prior to 1902 two were visible to the naked eye. All the others were found from the Draper photographs, and but for these photographs would probably never have been discovered.

The minor planet *Eros* was discovered in 1898 by WITT, but the examination of the Harvard photographs enabled Professor PICKERING to announce that it could be detected on fifteen or sixteen plates taken from 1893 to 1896, and that the spectrum photographed in January, 1894, was, like that of other planets, and the Sun, of the second type. A photograph taken in 1894 shows the planet as a long trail, while the images of the stars are round.

The vast work carried on at the two observatories under the name of the Draper Memorial included repeatedly photographing all portions of the sky, both Northern and Southern. By this means a map of the sky, showing all the brighter stars night after night, was made. The records of these observations furnish a complete history of the heavens every year since 1890. It is obvious from this that when any new object is discovered its history can be traced through these photographs. No such collection of photographs has ever been made, and the collection is as unique as it is vast.

The number of these photographs exceeds fifty thousand, and when we consider that these figures represent repeated surveys of the entire heavens—spectrographic, photometric, and photographic—and that these extend over a large number of years, one cannot but be impressed by the vast amount of work done in this undertaking, and with the energy and ability with which it was carried into effect.

In the year 1889, Miss CATHERINE BRUCE, of New York, placed at the disposal of Harvard University a large sum of money to purchase a 24-inch photographic telescope. When this telescope was completed it was mounted at the Arequipa

Observatory, where it has since been regularly used. This was a most welcome and material acquisition to the observatory, and an immense number of photographs have been taken with it.

The generous donor of this telescope was the same lady whose high appreciation of astronomical efforts caused her to present to the Astronomical Society of the Pacific the fund known as the Bruce Medal Fund, to which I have already referred. The medal now presented to Professor PICKERING is awarded from that fund in accordance with the directions from Miss BRUCE.

It is interesting to know that the generosity of Miss BRUCE in presenting the telescope above referred to undoubtedly assisted our medalist in his untiring efforts, and its use must be regarded as a factor in enabling him to win the medal now presented to him. Thus, Miss BRUCE has assisted astronomical science in two different directions, and on both sides of our continent.

Greatness in a commanding general consists not alone in individual effort and accomplishment, but in the ability to utilize the efforts of others. Professor PICKERING's accomplishments are along both of these lines. During his directorship of Harvard Observatory it has risen from a comparatively small institution to its present position as one of the leading observatories of the world. He has organized its work and directed it in fields of great usefulness, and in such a manner as not to conflict with, or overlap upon, the work of other observatories.

Through his foresight, a finely equipped observatory has been established in Peru under most advantageous climatic conditions, thus making Harvard Observatory, in this respect, the best equipped of all observatories.

In dwelling particularly on the genius of our medalist for organization, and for utilizing the efforts of others, the writer does not desire to detract in any manner from his many purely personal triumphs as an astronomer. His thorough grasp of the many sides of astronomical work cannot be better illustrated than by referring to his ability to create important instruments for astronomical work. Among these is his meridian photometer, an instrument for measuring and comparing the brightness of stars. While this instrument must

be regarded, to some extent, as an adaptation of previously existing instruments, Professor PICKERING has introduced so many important modifications as to make it in reality an original instrument.

Our Society has every reason to feel greatly proud of the manner in which this medal has been previously awarded. The list of awards is a roll of honor on which any scientist would be pleased to find his name inscribed, yet the writer knows that there is a feeling among members of our Society that the award to Professor PICKERING has been too long delayed.

In closing it may not be out of place to state a few of the many reasons why this medal is awarded to Professor PICKERING. As Director of Harvard College Observatory, he has given evidence of rare executive ability, of a remarkably clear and comprehensive insight into the great problems of sidereal astronomy, and of great resourcefulness in devising the most promising methods of attacking them, and in designing new instruments to carry out these attacks.

This unusual combination of gifts has enabled him to organize effective work on a large scale in at least three distinct though related fields—stellar photometry, stellar photography, and the study of stellar spectra. Thus, the Harvard College Observatory stands unique among the astronomical institutions of the world in possessing a vast library, to use Professor PICKERING's own happy comparison, of photographs of incomparable value, containing a complete history of the aspect of the entire heavens for nearly twenty years, and a complete record of the spectra of at least all stars as bright as the eighth magnitude.

In its record for the discovery of new and variable stars the observatory also stands without a rival, and only the Potsdam Observatory approaches it in the field of determining the photometric magnitudes of the stars.

To develop such an institution, and to successfully direct the execution of such extensive and important researches would seem to give sufficient exercise for the energies of the ablest man; but Professor PICKERING is also an enthusiastic and tireless observer, and his personal researches, especially in the study of variable stars and in the photometric measures of stars, particularly with his ingeniously devised meridian

photometer, constitute contributions to the advancement of astronomy of which any investigator might well be proud, and which in themselves would afford ample ground for the award of this medal.

The foregoing brief narrative will, I trust, to some extent show the wisdom of our Board of Directors in awarding this medal to Professor Pickering. Our medalist is still relatively a young man, and while his achievements have been vast, they are by no means ended, and we have every reason to believe that what has been done is but earnest of what will be done by him.

In the absence of Professor Pickering, I request you, Mr. Secretary, to transmit this medal to the distinguished scientist to whom it is awarded, with the congratulations and best wishes of the members of this Society, that he may long live to enjoy his honors so fairly won.

THE CROCKER ECLIPSE EXPEDITION OF 1908 FROM THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA.

By W. W. Campbell.

The Moon's shadow for the total solar eclipse of January 3, 1908, fell upon the Earth at sunrise in longitude 155° east and latitude 11° north, swept easterly across the central Pacific Ocean, and left the Earth at sunset on the western coast-line of Costa Rica. The shadow path crossed only two known landmarks—Hull Island, about seven hundred miles north of Samoa, and Flint Island (British), in latitude 11° south, four hundred and fifty miles northwest of the Island of Tahiti. The eclipse lasted sixty per cent longer and the Sun was much nearer the zenith at Flint Island than at Hull Island; and both were equally difficult of access.

On account of our position, on the Californian coast of the Pacific, and in view of our considerable experience in eclipse observation, there existed amongst astronomers a feeling that the Lick Observatory should, if possible, take care of this

eclipse This feeling was intensified by the knowledge that no other observatory was planning to send out an eclipse expedition. Our duty in the matter was in harmony with the strong desire to maintain, as far as practicable, the continuity of our eclipse series of observations, and to undertake the solution of certain definite eclipse problems.

The subject was brought to the attention of Mr. WILLIAM H. CROCKER early in the year 1907, and he generously undertook to defray the expenses of an expedition to Flint Island—the ninth Crocker Eclipse Expedition—provided a practicable method of transport could be found. There is excellent steamer service between San Francisco and Tahiti; but Flint Island is not on any steamer route. Regular steamers in the South Seas could not be induced, even for a consideration, to go a few hundred miles out of their way, because of insurance complications and of government mail contracts on fixed schedules and over definite routes. The chartering of a steamer exclusively for this purpose was prohibited by the cost. At this juncture it seemed to me that an appeal might with propriety be made to the Navy Department of our Government to transport the expedition. President WHEELER was pleased to approve this plan and to present my appeal. In response, the department expressed its desire and readiness to meet our requirements fully. It was arranged that the U. S. gunboat "Annapolis," under command of His Excellency, Captain C. B. T. MOORE, U. S. N., Governor of Tutuila, Samoan Islands, should meet us at Tahiti, transport the expedition to Flint Island about four weeks before the eclipse, and, two days after the eclipse, re embark and carry the expedition back to Tahiti It was my first pleasure and duty, on returning from Flint Island, to express to the department not only our thanks for this invaluable service, but our admiration for the clear-cut and business-like manner in which Governor MOORE and his staff carried out the letter and the spirit of the department's instructions.

It seemed very desirable that the observing programme should include a study of the heat radiations of the corona, by means of a bolometer. This important line of investigation had been inaugurated at the eclipse of 1900 by Mr C. G. ABBOT, of the Smithsonian Institution Observatory. This

fact, and his extensive experience and recognized skill in the use of the bolometer, made him the logical and best observer for this eclipse work. Accordingly, in April, 1907, it gave me pleasure to urge upon Dr. WALCOTT, Secretary of the Smithsonian Institution, and Director ABBOT, of the Astrophysical Observatory of the Institution, the desirability of dispatching an expedition to secure these observations, and to invite the suggested expedition to share in the travel and subsistence arrangements already under way for the Lick Observatory expedition. The proposal met with their approval. The scientific plans of the two expeditions were to be essentially independent, the travel and subsistence expenses to be shared on the basis of the number of persons in the two parties.

Professor E. P. LEWIS, of the Department of Physics, University of California, was invited to join the Crocker Expedition by virtue of his great skill in spectroscopic researches, in order that he might photograph the spectrum of the corona with his large quartz spectrograph.

The two expeditions sailed from San Francisco on November 22d, on the steamship "Mariposa," of the Oceanic Steamship Company. We numbered eight persons, and there were thirty-five tons of scientific instruments, tents, food, lumber, and general supplies The party consisted of Director and Mrs CAMPBELL, Astronomers PERRINE and AITKEN, and Assistant ALBRECHT, of Mt. Hamilton; Professor LEWIS, of Berkeley; Director ABBOT, of Washington, and his assistant. Mr. A. F. MOORE, of the University of California.

The twelve-day passage to Tahiti, in latitude 17°.5 south, was comfortable, but without special incident, as no ships were sighted after the second day out, and no land until the eleventh day, when three very interesting islands of the Paumotu group, or Dangerous Archipelago, were passed.

We reached Papeete, Island of Tahiti, on December 4th. The "Annapolis" came into the harbor on the morning of December 5th. By invitation extended through Governor MOORE, our party was joined on board the "Annapolis" by Professor BENJAMIN BOSS, in charge of the U. S Naval Observatory at Pago Pago, formerly assistant in the observatories at Washington and Albany. Three busy days in Papeete

were devoted to transferring our freight to the warship, securing a supply of mineral drinking-water, fruit and other perishables, a surf-boat for landing, and picking up our Tahitian carpenter, cooks, and laborers. We sailed for Flint Island on the evening of December 7th.

We approached Flint Island at noon on December 9th, with very considerable anxiety. On the "Mariposa" and in Papeete we heard much of the difficult and dangerous surf landing. The captain of the Tahiti schooner which runs to Flint Island about twice a year explained that landing was possible at only one point, on the northwest side, where a narrow and shallow passage into the flat coral reef had been blasted out; and if the surf were running high at that point we must wait on-board-ship until it subsided. This was true even when the surf-boats carried nothing more valuable than gunny-sacks full of cocoanuts and copra. The situation could be more serious for scientific instruments.

The visible parts of Flint Island are entirely of coral construction The waves break on the outer edge of a flat and level reef, whose average width is perhaps two hundred feet, whose height appears to be closely that of quiet water at high tide, and which nearly or entirely surrounds the island. At the outer edge the dip of the reef into deep water is remarkably steep. Sloping up from the inner edge of the flat reef is the dazzling white beach of broken coral, perhaps one hundred feet wide, which encircles the island, except that on the east side there are many irregularities in the way of rough and tilted reefs of solid rock not covered by broken coral. The entire area inside of the white beach consists of broken coral, more or less disintegrated, and is densely covered with trees. The form of the island is roughly that of a lozenge or kite, with greatest width east and west, nearly one mile, and length north and south slightly over two miles. Its greatest height, above mean sea-level, is twenty-two feet at the point, near the landing, where the buildings of the leasing company are situated. The average height is said to be thirteen feet

A few years ago the northern four fifths of the island were cleared of native trees and planted to cocoanut trees. There are no settled inhabitants. The lessees, Lever's Pacific Plantations Limited, maintain there an English manager and

about twenty-five native men and women, all engaged exclusively in the manufacture of copra.

The capable manager, Mr. E. F. HAWK, rowed out to the "Annapolis" with the pleasing intelligence that in his twenty-seven months' residence on the island he had never seen the surf running lower. Accordingly, with the help of the native boatmen and laborers, and of many of the ship's men, the landing in the surf-boats was rushed. By eight o'clock our forty tons of effects were on the beach and the "Annapolis" had turned back to Tahiti. The contents of our more than three hundred numbered packages were known in detail. This fact, and the placing of the large veranda and several rooms of the manager's bungalow at our disposal, made the starting of life on the island easy. It would be a dull imagination indeed which, at our first dinner, should not travel rapidly, to the accompaniment of roaring surf, the great cocoanut grove filled with nuts and noisy birds,[1] native figures moving noiselessly about, and the knowledge that a month of strenuous and interesting labor had begun.

The site for the station was selected at a point about two hundred feet directly east of the manager's bungalow, in the midst of the cocoanuts; a few missing trees here and there affording just sufficient unobstructed sky for convenient adjustment of the eight groups of instruments. The soil, of old coral, was, nearly everywhere in our camp, covered with rich grass. A tramway running from the landing slip immediately past the camp-site greatly facilitated the bringing up of our heavy supplies. The iron-roofed buildings, and the plantations' and our own steel tanks, affording, to our relief, an abundant supply of pure drinking-water, were less than one hundred yards away. The surrounding forest made an efficient break against winds from all directions; but, fortunately, the wind that rustled the treetops extended its cooling effects to the observers at their work. We were eight hundred and thirty feet (the meridian of the transit instrument) from the outer edge of the reef, and the altitude of the site was sixteen feet above mean sea-level. The ridge, altitude twenty-two feet,

[1] The old native name for Flint Island was Manuai, meaning "birds' resting-place." It is the home of tens of thousands of sea-birds, principally black terns, white terns, and frigate birds. Their chatter never ceased.

bearing the bungalow and the copra houses, was between us and the beach. The terrible hurricane of 1906 had brought the seas up to the crest of the ridge, throwing some of the buildings off their foundations, but the waves did not reach our position. This was comforting, inasmuch as the great loss of life and property caused in the South Seas by the hurricane is still the prevailing topic of conversation in that region. The sky when clear was remarkably pure and blue, resembling the Mt. Hamilton sky at its best. All in all, the conditions at the station, local and general, were better than we could have expected, though we were always conscious of the fact that the chances for clear sky at the critical time were not greater than two out of three.

As a result of prior correspondence with, and at the suggestion of, the American Consul at Tahiti, it was planned to provide cocoanut-thatch huts for the living-rooms, dining-room, kitchen, etc. Lumber for their frames, taken from San Francisco, was quickly put in place by our carpenter and helpers; and the natives brought cocoanut fronds, wove them into thatch, and fastened them on the roof- and side-frames. The eight houses were completed, furnished with the necessary shelves and tables, and occupied as rapidly as each was completed,—all in four days They were so easy of construction, so comfortable in tropical sun and rain, in fact so thoroughly adapted to their purposes, that the publication of a few additional details may be of value to future expeditions in tropical locations where thatch is available.

Each of the six sleeping huts was 10 x 14 feet, with side-walls 7½ feet high The gable roof was slightly steeper than an ordinary shingle roof. The thatch on the roof should be spread thickly, to turn the rain, but the walls need only a one-thickness covering. We found it advantageous to leave open the two side walls between the limits 6 feet and 7½ feet above the ground, as this afforded better air circulation A strip of cloth suspended by and sliding on a wire served as a door. Good dimensions for timbers are: Six side-posts, 3 x 3 inches, let into the ground a short distance; two gable-posts and one door-post, 2 x 3 inches, also let into the ground; two side-beams, 3 x 3 inches (with allowance for one-foot gable-roof projections); three cross-beams, 2 x 3 inches; six rafters on

each side, 2 x 3 inches (with allowance for one-foot eaves); one ridge board, 1 x 6 inches; two boards on the lower ends of rafters, 1 x 4 inches. Total, 160 feet, board measure. Diagonal ties in the wall and roof sections, of soft steel wire, $^1/_{16}$ inch, can be put in place, with six-penny nails, in a few minutes. The natives are accustomed to fastening the thatch in place with strong wrapping twine, but we found six-penny nails more satisfactory in every way. Each hut accommodated the large cots, baggage, and conveniences for two men.

The dining-room, 12 x 28 feet, had a thatch roof and gables, and mosquito-netting ceiling, walls, and doors. Double-door entrances, such as are used in connection with dark-rooms, would have been an improvement in keeping flies out

On a similar occasion we should construct two work-rooms, in the same manner, with thatch roofs and open sides, and also a food-supply hut.

While the huts were in process of building, the pier for the Repsold altazimuth was constructed and the instrument mounted thereon ready for use; the first time observation having been secured on the evening of December 11th. The grounds were cleared, the instruments and supplies were unpacked in the canvas tents, and the foundations were made ready. The weather was fine, barring short rains, during the first twelve days on the island, and the work of assembling, erecting, and placing the instruments in approximate position and adjustment was well along toward completion. In fact, there remained essentially only the final and delicate adjustments, the repeated trials of the instruments, the training of the observers, and the thousand and one changes in details which go to make up the difference between reasonably good results and those that are really worth while.

The Smithsonian Expedition's observing station was selected by Director Abbot at a point on the beach about 1,200 feet northwest of ours, in order that his bolometric observations prior to the eclipse might have one half the sky unobstructed by trees. The progress of Mr. Abbot's preparations was analogous to our own.

A few weeks before leaving California we learned with great pleasure that Mr. Francis K. McClean, F. R. A. S., of Tunbridge Wells, England, son of the late F. K. McClean,

F. R. S., distinguished contributor, both scientifically and financially, to astronomical progress, would conduct an expedition to Flint Island at his own expense. We looked forward to his coming with eagerness. His chartered ship arrived on December 23d. The party consisted of Mr. McClean, chief; Messrs. Brooks, Raymond, and Short, of Sydney; and Messrs. Walker and Winkelmann, of Auckland. Their camp adjoined ours on the southeast. We found them to be helpful and congenial neighbors, and we were sorry to lose their companionship on January 3d, immediately following the eclipse. Their photographs were to be developed on ship-board. We have not learned as to the degree of their success, but we trust that Mr. McClean is well satisfied with the results of their worthy and hard work. Mr. McClean most kindly brought Mr. Merfield, of the Sydney Observatory, to assist our expedition.

The days following December 20th were for the most part cloudy, but the nights after December 25th were nearly all clear. The preparations, proceeding at a normal rate, were completed in good time on the morning of January 3d. The "Annapolis" returned on the early morning of January 1st, bringing Consul and Mrs. Dreher from Tahiti to assist in the observations, and an abundant supply of ice for the photographic work.

A room in the bungalow was fitted up as a dark-room. This had been placed at our disposal by Manager H. Mortimer, who had succeeded Manager Hawk on December 19th. Mr. Mortimer was invited to assist in the observations.

The forenoon of January 3d was alternately clear and cloudy, with the clearness much in excess. About ten minutes before the eclipse was total, clouds formed rapidly, until the sky was densely covered. Just as the time-keeper called from his chronometer, "Five minutes before totality," a drenching rain fell, and all seemed lost save honor. At the end of two or three minutes the rainfall began to decrease and the clouds in the east gave signs of breaking. The signal "two minutes before totality" was called, as prearranged. Less than a minute before totality the slender crescent of the Sun showed faintly through the clouds, though a moderate rain was still falling. The rain and clouds grew rapidly lighter,

THE SOLAR CORONA.

and the last drops fell at two or three seconds after totality began. Immediately after the beginning of totality the corona was faintly visible through the thin clouds. These continued to disperse rapidly. During the second quarter of the total phase the clouds were extremely thin, though a thicker cloud obscured the Sun near the end of the second quarter; and during the third and fourth quarters the sky was clear of clouds, but a thin haze could be distinguished. There was no wind.

About ten seconds before totality, the rain having nearly ceased, the order was given to the workman seated on top of the outer of the two towers supporting the forty-foot camera to remove the tarpaulin from over the lens. The order was executed promptly and the remnant of the Sun's crescent was first seen by the observer inside of the camera just one second before totality, and he immediately called out "One second before."[1] The signal "Go!" was called by the observer at the instant when the crescent disappeared. Such of the instruments as were still covered, awaiting the end of the rain,—for example, the larger cœlostat,—were uncovered within a few seconds, and the programme of observations was thenceforth carried through without a single slip. The twenty instruments, driven by seven clocks, and the eleven observers and two helpers did their work to perfection. Two spectrographic exposures planned for the twelve seconds immediately preceding totality were necessarily omitted, and some of the sensitive plates were thought to be damaged by getting wet in the sudden downpour. The remaining exposures were expected to give good results; and such proved to be the case when the plates were developed, during the following two nights. All of the instruments were in perfect focus and adjustment.

This eclipse was a very "light" one,—not nearly so dark as those of 1898, 1900, and 1905, as observed by the writer.

The accompanying views of the station are from photographs secured shortly after the eclipse was over. The negative of the group of observers was unfortunately much underexposed. The

[1] It had been arranged that this observer should call out "Forty-eight seconds before" and "Nineteen seconds before [totality]" when the uneclipsed crescent had certain definite computed lengths, but the impossibility of uncovering the lens while the rain was still falling prevented the giving of these signals.

canvas covering of the outer tower supporting the forty-foot camera was removed before photographing that instrument.

The repacking of the instruments proceeded rapidly, and, the surf being very favorable, the most valuable articles, such as chronometers, lenses, mirrors, prisms, and clocks, were put on-board-ship on the morning of January 4th. As soon as the last of the eclipse negatives was dry all were packed with extreme care and sealed in tin. These packages, accompanied by the observers in two surf-boats, were the last to go on board, at 11 o'clock of January 5th. By this time the surf had risen, one of the boats shipped considerable water, and the experiences of both boats in passing out through the surf were certainly exciting. The "Annapolis" headed at once for Tahiti, which we reached at daylight of the 7th.

Our departure from Flint Island was not unmixed with regret. A few members of the party were heard to wish that they could remain longer to enjoy the wonderful beauty of our surroundings, a result that strenuous eclipse duties did not adequately permit. Our camp-life was wholly devoid of unpleasantness. There had been time on a few evenings for experiences that will never be forgotten. A successful turtle hunt on the coral beach, in alternating moonlight and tropical downpour; a Christmas-tree, with presents and toasts supplied by friends who remained behind in Papeete; a Christmas dinner in which Mr. McClean's party and ours joined forces; and a poetic contest entered into by nearly all members of both parties, to determine who should be called the Poet Laureate of Flint Island. Every member of the party was well every minute, notwithstanding exposure to tropical sun and frequent drenchings; and this happy result is perhaps sufficient comment on the judgment and efficiency of the commissary department.

Six days on the Island of Tahiti were devoted to closing up the local business affairs, to observing for longitude at Point Venus, to sight-seeing, and to several exceptionally agreeable social matters. We sailed north on the 13th, and after a stormy passage entered the Golden Gate on the 25th. The instruments and eclipse photographs reached Mt. Hamilton uninjured early in February.

Following is a brief description of the instruments, observing programme, and results secured. The results obtained with

each instrument and for each problem will be published later in detail.

TIME, LATITUDE AND LONGITUDE.

It was the intention that Dr. AITKEN should observe Moon culminations both before and after the full Moon of December 19th, with the Repsold altazimuth instrument, to determine the longitude of the station; taking into account the fact that the Moon's right ascension, as measured at Mt. Hamilton on four nights in October and November by Professor TUCKER, was $0^s.41$ greater than the ephemeris value. Unfortunately, there were thick clouds at the times of transit on some ten successive nights, and only one culmination was observed,—on the night of December 25th. The resulting value of the longitude, $10^h\ 7^m\ 10^s.0$ west, is necessarily of small weight. Our two chronometers, transported from the clock of the Students' Observatory, Berkeley, to Flint Island, and back to the clock in Berkeley, gave a longitude of $10^h\ 7^m\ 11^s$ west. A comparison of time observations by transits secured on January 3d, at the eclipse station, with sextant observations of the Sun obtained at Point Venus, Tahiti, on January 8th, made the longitude of our station $10^h\ 7^m\ 16^s.8$; assuming the position of Point Venus to be as quoted in the "Connaissance des Temps."

Dr. AITKEN's observed meridian altitudes of a considerable number of stars on two evenings gave results for the latitude as follows:—

December 13th, $-11^\circ\ 25'\ 26''.6 \pm 0''.62$
December 26th, $-11\ \ 25\ \ 27\ .1 \pm 0\ .41$

The adopted co-ordinates of the instrument, located near the center of the groups of instruments, are:—

Longitude........ $10^h\ 07^m\ 13^s$ W. $\pm 4^s$
Latitude.......... $-11^\circ\ 25'\ 26''.8\ \pm 0''.4$

The concrete pier was left standing. The entrance to the landing-slip in the reef is estimated to be 1,200 feet northwest of the pier.

Throughout totality the second-beats of the chronometer were called off by Dr. AITKEN, as guides to the observers in the Lick and British parties.

TIMES OF BEGINNING AND ENDING

The predicted times of beginning and ending of totality, based upon American Ephemeris data, and the adopted longitude and latitude of the station were:—

Beginning,	9^h	22^m	43^s	Greenwich mean time
Ending,	9	26	44	" " "

The times observed by Dr. AITKEN without telescopic assistance, and by Dr. ALBRECHT inside of the forty-foot camera, agreed within a second, and were: —

Beginning	9^h	22^m	20^s
Ending	9	26	12

The observed duration, 3^m 52^s, was 9^s shorter than the predicted duration; and mid-totality came 27^s ahead of the predicted time. The observed excess of the Moon's right ascension, referred to above, would account for fully 20^s of the advance. The remaining few seconds are no doubt due to additional slight errors in the assigned positions of the Sun and Moon, and possible small errors in our adopted longitude.

THE FORTY-FOOT CAMERA.

This camera was erected under the personal supervision of Mr. CAMPBELL, the adjustments were made by Messrs. CAMPBELL and ALBRECHT, and the observations were secured by Dr. ALBRECHT.

"The outside general features of this instrument, designed by Professor SCHAEBERLE for observing the eclipse of 1893, are shown in the reproduced photograph of the station. In this camera the Clark lens of five-inch aperture, the combination tube of iron and cloth, and the plate-carriage moving by clock-work on an accurately curved metal track, are supported entirely independently of each other. The lens is mounted on the top of a strong interior tower, surrounded by a cloth-covered outer tower, whose duties are to support the upper end of the camera tube and to prevent the wind from shaking the inner tower; a system of lens support devised by Mr. CAMPBELL to meet conditions on the plains of India in 1898. With this form of support the camera can easily be pointed near the zenith if necessary (as in Sumatra by Mr. PERRINE in 1901); and the advantage[1] of having the lens at a good height above the radiating soil is preserved. The towers

[1] A comparison of results obtained with the tower and horizontal forms of telescopes at the Solar Observatory, Mt. Wilson, in 1907, is strongly confirmatory of this advantage.

THE 40-FOOT CAMERA

are easily constructed, the various parts of the camera are quickly put into their approximate positions from simple computations, and the final adjustments are readily made"—*Extract from the Lick Observatory-Crocker Eclipse Expedition to Spain, in 1905. Publications A. S. P., February, 1906*

Lumber for the towers and cement for the footings were taken from San Francisco. They were constructed at the expense of two days' labor. The focal length being 40.00 feet, and the Sun's altitude at mid-totality being 73° 58′, the center of the lens was placed 38 feet 5.35 inches higher than the center of the sensitive plate, and 40 feet above the ground under the towers The tent covering the traveling plate-carriage was set in a pit excavated for this purpose to a depth of fifteen inches The excavation was made only in order that firmer soil to support the carriage might be found.

Excepting the work of our expeditions, nearly all large-scale coronal photography of the past ten years has used horizontal cameras, with cœlostats to reflect the coronal radiations into them,—following the re-invention of the cœlostat by LIPMANN in the middle nineties. While the cœlostat has evident advantages in certain spectrographic and other researches on the Sun, or bright bodies lying near the celestial equator, its use in large-scale coronal photography has always seemed to us to be unwise. That a horizontal camera is slightly the more *convenient in construction* is true, but this item is entitled to no consideration if another form of camera is *better*. The factors of chief significance appear to be as follows:—

1. The tower camera has its lens and its tube at a good height above the radiating soil; all parts of the horizontal camera are near the soil. The "seeing" with the former should be the better.

2. The tower is the more readily ventilated shortly before totality occurs. (The plate holder tent is always protected from direct solar radiation on the day of the eclipse by tent flies or fresh foliage Canvas protection for the white-canvas camera-tube could readily be provided if thought desirable.)

3. The tower camera has the simpler optical equipment; the introduction of extra optical pieces and surfaces, such as the cœlostat mirror, is always to be avoided, other things being equal.

4. The focus of the tower lens remains practically constant; the focus of the cœlostatic optical train usually changes rapidly with changing temperature—and the temperature can be expected to fall rapidly during the hour preceding totality.

5. Driving-clock errors and irregularities are not magnified in the Schaeberle tower camera; such errors and irregularities in a large cœlostatic camera are magnified greatly on the sensitive film.

6. The lens in the Schaeberle tower camera is collimated for the Sun at mid-totality; but the lack of collimation at the beginning and ending of totality appears to be negligible even for eclipses of long duration, with the lens of aperture 5 inches, and focal length 480 inches—ratio 1 : 96.

7. It is probably as easy to protect the inner tower as the cœlostat against wind vibrations.

Six exposures were made with the forty-foot camera, on Seed plates, No. 27, as below:—

Exposure	No 1..................	4	seconds
"	No. 2..................	2	"
"	No. 3..................	32	"
"	No. 4..................	16	"
"	No. 5..................	64	"
"	No. 6..................	32	"

Returning sunlight fell on the last plate for a fraction of a second. The seeing was splendid, the focus and clock-driving were perfect, and the negatives are excellent. A reduced copy of No. 4 is reproduced in the illustration. The diameter of the Moon's image on the original negatives is 4 74 inches. It is scarcely necessary to say that the rich detail of the original is largely lost in the half tone print. Two of the negatives have "standard squares" near one edge, made by exposing the squares to the light of a Hefner amyl-acetate lamp on the night preceding the eclipse.

THE FLOYD CAMERA.

This camera, with Clark lens of 5-inch aperture and 67-inch focal length, had for its purpose the recording of the corona on a small scale, giving images especially valuable in the study of the mid- and outer-coronal structures. It was mounted

horizontally and received its light from a part of the 12-inch cœlostat mirror. Mr. CAMPBELL attended to the mounting and adjustments, in connection with the difficult placing and adjusting of the large moving-plate spectrograph, which received its supply of light from the same mirror.

The exposures were made on eclipse day by Mr. MORTIMER, on Seed plates, No. 27, as follows:—

No. 1	Short as possible
No. 2	1 second, when ready
No. 3	2 " " "
No. 4	4 " " "
No. 5	8 " " "
No. 6	16 " " "
No 7	8 " at $3^m\ 30^s$
No. 8	2 " when ready

The exposures did not begin immediately following the beginning of totality, as the cœlostat covering was not removed until after the last drops of rain fell. The negatives are all of great excellence. The longer streamers are recorded out to two solar diameters. The general form of the corona is shown in the reproduction of negative No. 6, but the exquisite detail of the original is lost.

The longer streamers are rather uniformly distributed around the Sun, but the strong inner corona is considerably stronger in the east and west than in the polar regions The 1905 inner corona was about equally strong in the equatorial and polar regions.

POSSIBLE CORONAL EXTENSIONS.

It was the special duty of Consul DREHER to look for and determine the positions and lengths of possible coronal streamers of great extent, such as those observed by Professor NEWCOMB at the eclipse of 1878. No extensions greater than those recorded on the Floyd negatives were visible Dr. PERRINE was also to look for the same phenomena. The slight changes in the other parts of his programme, made necessary by the rain, curtailed the time assigned for the observations just referred to, but in the short interval that was available he saw no long extensions.

THE INTRAMERCURIAL-PLANET CAMERAS.

The search for possible intramercurial planets was continued by Dr. PERRINE on essentially the plans used at the eclipses of 1901 and 1905 There were eight cameras, provided with Clark lenses of 3-inch aperture and 11-foot 4-inch focus. Four of these cameras, using plates 18 x 22 inches, were fastened together rigidly, and so mounted on a clock-driven polar axis that they covered a region 28° long, in the direction of the Sun's equator, by 9°.25 wide. Another set of four cameras, using plates 16 x 20 inches, were similarly mounted, so as to cover the same region as the first group, excepting a narrow strip around the edge of that region Both groups of these cameras, and the group of polarigraphs, are shown in the illustration.

One plate was exposed in each camera during the last three minutes of totality. Duplicate exposures were thus obtained for each of the four areas into which the region was divided One of the groups of cameras was set up on Mt. Hamilton in October, before starting to Flint Island, and duplicate exposures of precisely the same region were obtained after sunset The four sets of negatives furnished sure and convenient means of determining whether objects on the plates were stars, planets, or defects.

These cameras and their driving-clocks worked perfectly In the sudden downpour of rain immediately preceding totality it was not possible to protect everything, and a little water got into these instruments. Some of the negatives are marked by narrow bands where the rain-water ran across them. Until after our return to Mt. Hamilton it was thought that the photographs were damaged to such an extent that the value of the intramercurial search would be seriously impaired; and our public announcements embodied this view. It is gratifying to announce, as a result of Dr. PERRINE's preliminary examination of the plates, that these fears were groundless. He has found the images of fully three hundred stars on the photographs, down to the ninth magnitude; and, surprising to relate, the rain-streaked areas contain the images of all the known stars that he expected to find therein. All images have been identified as those of well-known stars. The search has not been finished, but the expectation of finding images of unknown bodies is small

COELOSTAT, MOVING PLATE SPECTROGRAPH AND FLOYD CAMERA

indeed. In my opinion, Dr. PERRINE's work at the three eclipses of 1901, 1905, and 1908 brings the observational side of the famous intramercurial-planet problem definitely to a close. It is not contended that no planets will be found in the intramercurial region: it would not be especially surprising if small ones should be discovered at some future time; but it is believed that their mass would be inadequate to disturb *Mercury's* motion.

Professor BENJAMIN BOSS was an efficient assistant to Dr PERRINE in mounting these cameras and in securing the observations.

THE MOVING-PLATE SPECTROGRAPH.

The spectrograms obtained at the eclipses of 1898, 1900, and 1905, on a continuously moving plate, showed that this is a most advantageous method for recording the changing spectrum of the Sun's edge as the edge is gradually covered or uncovered by the Moon. The dispersive power was supplied in 1898 by a plane grating, and at the other eclipses by two 60° prisms. The instrument used at Flint Island is shown in the illustration The light, supplied by a part of the cœlostat mirror, passed through three 60° prisms, whose circular apertures are 2⅛ inches, and thence through the camera lens, of 60-inch focus, to the plate. The cœlostat may be seen, in the photograph, under the camera-box section of the spectrograph; and the first prism is visible to the right of the cœlostat. The entire spectrograph was so mounted that it could be rotated about the axis of the light-beam incident upon the first prism-surface, in order to place the prism-edges parallel to the central elements of the uneclipsed thin crescent near the beginning and near the ending of totality. The central sections of the crescents in the cœlostat images made angles of 27° 06′ and 6° 18′, respectively, with the horizon. The instrument was placed in its computed position by means of a theodolite, and the spectrum on the day of the eclipse fell upon the sensitive plate in the desired position, as nearly as could be estimated.

Immediately in front of the plate was a slit $^1/_{10}$ inch wide, which permitted the central section of each crescent in the spectrum to fall on the plate. A motion of approximately $^1/_{10}$ inch per second was given to the plate by the piston on the plate-holder slide. The piston was operated by a weight.

The linear dispersion is such that the region λ 3700 to λ 5300 covers 13 inches. The focal surface is strongly curved; the tangent at the center of the field lying ¾ inch outside the focal positions at the ends. A film 7 x 14 inches was used. A special plate-holder held the film firmly in position.

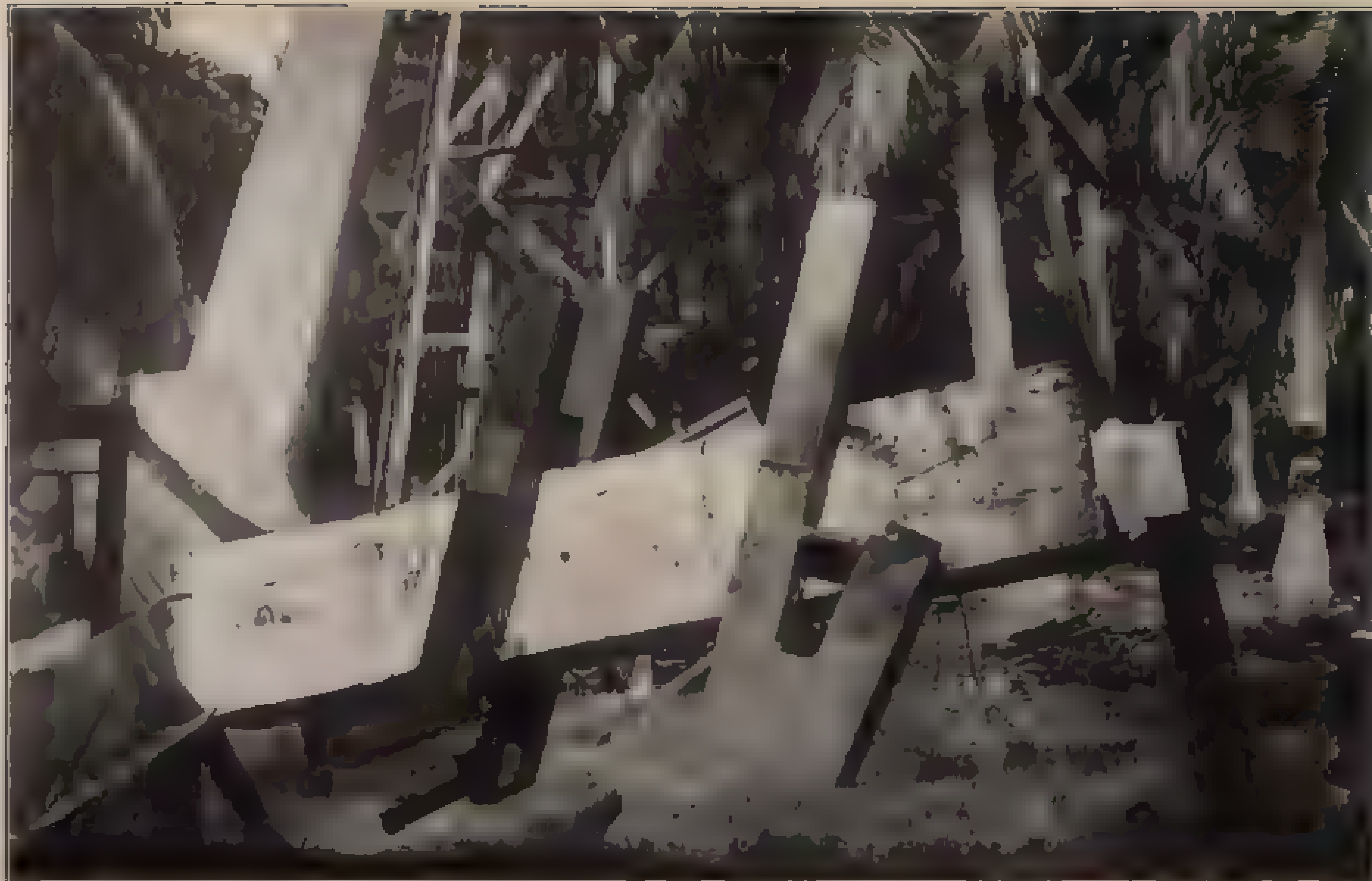
An exposure extending from fifteen seconds before to fifteen seconds after totality began was planned for, but omitted on account of the rain. The mirror was not uncovered until some five seconds after totality began. A corresponding exposure was made at the end of totality, with entire success, save that the negative is somewhat overexposed. The photograph is in good focus, from λ 3800 to λ 5100. Hundreds of bright lines are recorded in lengths and at times showing the thickness and locations of their corresponding vapor strata, and their changes into dark lines as the photospheric surface was uncovered by the Moon The photograph contains a mine of information as to the structure and composition of the Sun's higher atmosphere. The series of four photographs may be said to constitute the basis for a study of the stratification of the Sun's atmosphere.

THE THREE-PRISM SPECTROGRAPH.

A spectrograph of high dispersion, containing three very dense glass prisms, was used in the hope of recording the green coronal line, in order to determine its wave-length with great accuracy. The solar spectrum was impressed upon the plate immediately after the end of the total eclipse, for reference. No trace of the coronal line exists on the plate, undoubtedly because of the strong absorption of the prisms. As is well known, there are no available plates very sensitive to light of wave-length λ 5300.

THE SINGLE-PRISM SPECTROGRAPHS.

Two single-prism spectrographs were designed by me for efficiency in recording the continuous spectrum of the corona. These and the three-prism spectrograph described above were mounted on one clock-driven polar axis, as illustrated. All were adjusted with great care by Dr. Albrecht, and the programme of observations at the time of the eclipse was carried out perfectly by Mr. Merfield. The slits of all the instruments extended east and west centrally across the Sun's image.



THREE PRISM AND TWO ONE PRISM SPECTROGRAPHS

bright lines. A SCHROEDER's metal mirror, belonging to the Lick Observatory, mounted on a clock-driven (at one half the diurnal rate) polar axis, reflected the light horizontally into the quartz image-lens. The collimator- and camera-lenses of quartz are of 9.2^{cm} aperture and one meter focus. The effective rectangular apertures of the two CORNU quartz prisms are 6×6.8^{cm} The length of the spectrogram from *D* to λ 3000 is 14^{cm}.

The slit was adjusted to tangency to the Moon's limb at a point 16° 42′ north of the highest point of the image on the slit, as this was the mean of the positions of tangents to the two points of contact of the Sun and Moon.

It was intended to obtain a spectrum of the first flash, but the rain prevented.

The exposure on the coronal spectrum extended from 0^m 15^s to 3^m 30^s. The photograph shows a strong continuous spectrum extending from λ 3200 to λ 5100 Here and there in the middle ultra violet, and nowhere else, are very faint indications of superimposed dark-line spectrum, of the same width as the continuous spectrum. This width is 3.1^{mm}. Superimposed on the continuous spectrum are about twenty-five sharp lines, none of which appears to proceed from the chromosphere. Some are so faint that their existence may be doubtful, while others may be maxima due to the superimposed dark-line spectrum. Two rather strong bright lines appear to be new. Dr. LEWIS further finds from the photograph that the Sun is relatively much richer in ultra violet light than the corona, from which fact the much lower effective temperature of the latter is safely inferred.

The west limb of the Moon was made tangent to the slit just at the end of totality, and an exposure on the flash spectrum,—overexposed on account of the duration being shorter than expected,—recorded the tips of some eighty strong, bright crescents projecting beyond the solar spectrum.

A fuller description and discussion of Dr. LEWIS's important results will appear later.

THE POLARIGRAPHS.

The effects of polarization in the coronal light were observed by Dr PERRINE by means of four special cameras mounted

THE POLARIGRAPHS AND INTRAMERCURIAL CAMERAS.

on a clock-driven axis. There was the camera of 20½ inches focus, having a double-image prism in front of its objective, that was used at the eclipses of 1901 and 1905. The other three cameras, of 50 inches focus, were designed by Dr. PERRINE and used, in 1905, in Spain. Two of these have plane-glass reflectors in front of the objectives to serve as analyzers, while the purpose of the third pointed directly to the Sun, is to secure an unpolarized image of the corona as a standard of comparison. The aperture of this direct camera was reduced, so that the image obtained with it would be approximately of the same intensity as the (unpolarized) images formed in the other two cameras after reflection from the plane-glass surfaces. The plane-glass analyzers were set at the angle of maximum polarization. Their principal axes were adjusted, one parallel to a north-and-south line and the other to an east-and-west line, through the corona.

The performance of all the polarigraphs was exactly as planned. Mrs. CAMPBELL and Mrs DREHER assisted in making the observations. The four series of negatives, with exposures of from 2^s to 60^s, appear to be perfect in every respect. They show strong polarization effects in the corona, perhaps even to the very edge of the Moon's image All of our previous polarization observations were secured through clouds; but, so far as we may judge from a comparison with the present series, the clouds were without appreciable effect on the character of the images.

It is hoped to make accurate photometric measurements of the polarization series of photographs.

THE PHOTOMETER.

Mounted on the same axis as the polarigraphs was a photometer, in all respects resembling an ordinary camera with the lens removed The light from the corona and surounding sky passed directly through the aperture to the photographic plate Two plates were exposed when the sky was entirely clear of clouds Small standard squares on the plates had been exposed to the light of the Hefner lamp on the preceding night. Using these standards as a basis of comparison, it should be possible to obtain a satisfactory measurement of the total effective photographic action of the coronal radiations

These plates contain the data for measuring the sky brightness surrounding the corona. Dr. PERRINE's examination of the negatives shows that the effective photographic radiations of the corona came almost wholly from its extreme inner parts,—from within 1′ or 2′ of the Sun's surface.

The requirements of a large eclipse expedition are many; but, as I have stated on a previous occasion, the astronomer who is charged with the duty of conducting its affairs is an optimist, for at all points where he needs assistance there are men ready to help him.

The present expedition is under many obligations.

The first reference must be to the great service rendered by the Navy Department of our Government, acting through His Excellency, Captain C. B. T. MOORE, U. S. N., governor of Tutuila, Samoa, who was in command of the U. S. gunboat "Annapolis." To meet us at Tahiti, to transport the expedition to Flint Island early in December, to come a second time to the island, re-embark and carry the expedition back to Tahiti, required an absence of seven weeks from his Samoan post of duty,—an interval but two weeks shorter than our absence from California. Special thanks are due to Governor MOORE not only for the able manner in which the department's instructions were carried out, but for the constant personal and professional attention that he gave to the needs of the expedition and the comfort of its members.

Our cordial thanks are extended also to the able corps of officers of the "Annapolis"—

Lieut. W. G. BRIGGS, U. S. N.
Lieut H. B. SOULE, U. S. N.
Dr. M. E. LANDO, U. S. N.
Paymaster J. M. HILTON, U. S. N.
Warrant Machinist J. F. GREEN, U. S. N.

The petty officers and the gallant crew rendered splendid and heavy service in transferring our freight twice in Papeete Harbor and twice at Flint Island.

Lever's Pacific Plantations Limited, lessees of Flint Island, gave permission to establish the observing station on the island, and instructed their agents in Papeete, S. R. MAXWELL & Co (Mr. BUNCKLEY, superintendent), and their successive managers on the island, Messrs HAWK and MORTIMER,

to meet the requirements of the expedition in every possible manner. Their instructions were carried out most liberally. The native labor was available, at my call, for the landing and re-embarking of the expedition, for the erection of huts, and for many other duties. As previously mentioned, the resources of the bungalow were shared by us for several days, and one room in it was devoted to dark-room purposes. The supply of fresh water was divided with us, half a dozen great turtles were sent in to the commissary department, and a score of other valuable services were rendered by Messrs. HAWK and MORTIMER. Mr. MORTIMER assisted in the observations. We earnestly thank the Lever's Pacific Plantations Limited and their officials, Mr. BUNCKLEY, Mr. HAWK, and Mr MORTIMER, for the invaluable services that are here but imperfectly mentioned

The Government of Tahiti, acting under instructions from Paris, kindly expedited the transfer of our freight and baggage through the port of Papeete.

Our country is worthily represented by the American Consul in Tahiti, Dr. JULIUS D. DREHER During the period of organization he supplied me with reliable information and valuable suggestions on a variety of subjects relating to the work and living arrangements of the expedition. Prior to our arrival he had arranged a score of business matters, in accordance with my statement of needs, which enabled us to proceed promptly to Flint Island. Dr. and Mrs. DREHER were the guests of the expedition during eclipse week, and they assisted in the observations. The pleasures of our nine days at Tahiti were constantly added to by their thoughtful acts of kindness.

Many favors were extended to the expedition by the Oceanic Steamship Company, acting through Captain H. M. HAYWARD, of the steamship "Mariposa," and his officers, through General Passenger Agent COCKROFT, of San Francisco, and through Agent MEUEL, of Papeete.

Mr. J. LAMB DOTY, Mr. F. W. WAKEFIELD, and Mr and Mrs. F. W. SEARBY, all former residents of Papeete, supplied useful information and advice.

Professor BENJAMIN BOSS, in charge of the U. S. Naval Observatory at Pago Pago, Tutuila, was an efficient member of the expedition throughout our stay of twenty-seven days on Flint Island.

C. J. Merfield, Esq., of the Sydney Observatory, was a capable and busy member of our expedition during the eleven days that the British party was on the island.

Thanks are extended to Mr. McClean for his generosity in transporting Mr. Merfield from Auckland to the island and return, and for the spirit of comradeship and good cheer which he and all the members of his party supplied.

It was a rare pleasure to have Professor Lewis in our expedition.

The presence of Director Abbot and Mr. Moore, of the Smithsonian Institution Expedition, was at all times a happy arrangement. It was a great satisfaction to every member of our party that Mr. Abbot's scientific plans were carried out exactly as planned.

I gladly acknowledge the able assistance of my colleagues, Messrs. Perrine, Aitken, and Albrecht, whose services were always available, both in the preparations and at the station. It has been the lot of Dr. Perrine and myself to be associated in the observation of three eclipses. A veteran of five eclipses, he has no superior as an eclipse observer; and his services, placed unreservedly at my command, were held in high esteem.

A BOLOMETRIC STUDY OF THE SOLAR CORONA.

By C G Abbot

The Smithsonian Institution was represented among observers of the eclipse of January 3, 1908, by a small expedition including the writer and Mr. A. F. Moore, of Los Angeles. Our charges were defrayed by the Institution, but we went by invitation and with the co-operation of Director Campbell, of the Lick Observatory, and shared in the benefits of the careful provision which he made for the general welfare and success

We proposed to measure, with that extremely sensitive electrical thermometer called the bolometer, the intensity of the radiation of the solar corona, and to determine the quality of coronal light as compared with sunlight.

STATION OF THE SMITHSONIAN INSTITUTION EXPEDITION

In the year 1900 the first bolometric observations of the corona were made by Smithsonian observers. From these observations it was inferred that, as regards quality, the radiation of the inner corona was far richer than that reflected from the Moon in visible light. In view of this consideration and others, the inferences drawn by the writer from the bolometric study of the corona made in 1900 were unfavorable to the view that the radiation of the inner corona is produced mainly by the incandescence of matter heated to high temperatures by reason of its proximity to the Sun. The bolometric observations at Flint Island were designed to test the inferences above referred to and to measure more definitely the quantity and quality of the coronal radiation.

APPARATUS.

Referring to the accompanying illustration, a concave mirror of 50^{cm} diameter and only 100^{cm} focus, mounted equatorially and driven by a clock, served to produce a very intense image of the corona. A small guiding telescope was attached to the mirror frame so that the observer might point toward any desired object. In the focus of the mirror was placed the bolometer. A glass plate 3^{mm} thick was fixed close to the bolometer, between it and the mirror, so that the radiation examined was thereby limited to wave-lengths less than about 3μ. About 10^{cm} in front of the bolometer was a blackened metal shutter, which cut off the beam except when designedly opened. The opening of this shutter, therefore, exposed the central part of the bolometer to such rays as are transmissible by glass. Between the shutter and the glass plate, and close to the latter, was a special screen composed of a thin stratum of asphaltum varnish laid on one side of a plane parallel glass plate 3^{mm} thick. This screen was held out of the beam by a spring, except when designedly interposed. Its property, when used, was to cut off nearly all the visible part of the radiation, while transmitting nearly all of the infra-red rays transmissible by glass. By interposing this absorbing screen the proportion of the observed radiation which lay in the infra-red spectrum could be roughly determined.

The equatorial was set up at Flint Island on the beach at about 12^{m} distance from the galvanometer used for observing

the indications of the bolometer. Two galvanometers were provided, exactly alike in resistance and general construction, and arranged so that if at the last moment any accident should happen to one the observer might pass at once to the other.[1] A thatched hut, shaded by palm trees, sheltered the galvanometers and their appliances, and was found to give most satisfactory protection both from heat and rain. During the eclipse a rise of temperature of one bolometer strip of about $0^{\circ}.000,01$ C. would have produced 1^{mm} deflection of the galvanometer. It is possible to detect temperature changes of $0^{\circ}.000,000,01$ C. with the bolometer, under special conditions, but the sensitiveness employed was regarded as good for a temporary installation.

THE OBSERVATIONS.

The approach of totality was uncommonly exciting on this occasion. Early in the morning the sky was overcast with thin high clouds, but these gradually grew thinner, so that after 9 A. M. the prospects indicated a streaky sky, containing something almost too thick for haze, but almost too thin for cirrus clouds. These prospects were fulfilled exactly during totality, but in the quarter of an hour next preceding a thick cloud came up, rain fell fast from $11^{h}\ 8^{m}$ to $11^{h}\ 14^{m}$, and the sky became clear of the low cloud only fifteen seconds before totality at the Smithsonian station. The rapid change from fair prospects to completely discouraging ones, and the return to good conditions just at the critical time, will long be remembered. Our entire immunity from rain during totality was due to the fact that our station was about one thousand feet north of the one occupied by the Lick Observatory.

The intensity and quality of sunlight was determined within twenty-five minutes of totality, both before and after, and during totality measurements were made at five different regions of the corona and on the dark Moon. A general summary of the results of these and other observations follows:—

[1] This prudent measure was suggested by Mrs. ABBOT.

INTENSITY OF RAYS (OBSERVED THROUGH GLASS).

Source	Intensity for unit angular area.
Sun near zenith, Flint Island......	10,000,000
Sky 20° from Sun, Flint Island....	140
Sky far from Sun, Flint Island....	31
Sky average, Flint Island.........	62
Sky average, Mt. Wilson, Cal......	15
Moon at night, Flint Island.......	12(?)
Moon during eclipse, Flint Island..	0
Corona 1/10 radius from Sun.....	13
Corona 1/4 radius from Sun.....	4
Corona 3/4 radius from Sun.....	0

PROPORTION OF RAYS WHICH ASPHALTUM TRANSMITS.

Source.	Determination. I.	II.	Mean (Weighted).
Sun 3/10 radius from limb..	0.333	0.331	0.332
Corona 1/10 radius from limb	0.343	0.384	0.364
Corona 1/4 radius from limb	0.387	0.323[1]	0.362
Moon at night............	....	....	0.5
Sky, zenith day............	....	....	0.23

DISCUSSION OF THE RESULTS.

When we recall the extreme brightness of the sky within a single degree of the Sun, as compared with that 20° away, and consider also the figures just given, it seems very unlikely that the corona will ever be observed without an eclipse.

The nature of the radiation of the inner corona has been supposed by some to be principally reflected solar radiation, by others to be principally due to the incandescence of particles heated by reason of their proximity to the Sun, by others to be principally luminescence perhaps similar to the Aurora, and by some as a combination of all of these kinds of radiation.

The spectrum of the corona is mainly continuous, but has some inconspicuous bright lines, and in its outer part has dark solar lines. Undoubtedly there is sunlight reflected by the matter of the corona, and no less surely the corona must be hot. As for the idea of luminescence by electrical discharge, though the streamers of the corona are a reminder of the Aurora, one hesitates to recommend an explanation involving

[1] This observation is entitled to only half the weight of the others.

a thing so little understood, so that we will here speak only of the incandescence and reflection of the corona as sources of its brightness. The bolometric results indicate that the coronal radiation differs but little in quality from that of the Sun, and is in fact far richer than the reflected rays of the Moon in visible light, although less rich than sky-light.

These results indicate that if produced by virtue of high temperature, the coronal radiation must have come from a source almost as hot as the Sun, which is upwards of 6000° absolute. Such temperatures as this are too high for the existence of any solids or liquids, unless under high pressures not found in the corona, so that if the light is due to the high temperature of the corona itself, the corona must be gaseous. But if it is gaseous, its spectrum should consist chiefly of bright lines, and this is not the fact. Hence, it would seem that the coronal radiation, if it is produced by temperature, has its cource in the Sun itself, and is merely reflected by the matter of the corona, like the light of our atmosphere. But if the coronal rays are reflected, they would be bluer than sunlight, if the material there is gaseous; and as they are not, the coronal material may be supposed to be composed of solid or liquid particles to a considerable extent. But it is objected that only the outer corona shows the characteristic dark lines of the solar spectrum, and that these are absent in the region of the corona now being considered. May it not be that the temperature of the inner corona is so high that gases are present there along with the solid and liquid particles, so that the bright-line spectrum of these gases may be present and be superposed upon the reflected solar spectrum? In this case, the bright rays of incandescence would fall exactly upon the dark lines of the solar spectrum, and tend to obliterate them At points in the corona more remote from the Sun the gases would cool to liquid drops, or solid particles, or become excessively rare, so that the bright-line spectrum of incandescent gas would fade away, leaving the dark lines of the reflected solar spectrum predominant.

This line of explanation seems to me to accord with the facts observed, but I give it merely as a suggestion.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1908.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter	May 8,	3^h	23^m	A.M.	First Quarter	June 6,	8^h	56^m	P.M.
Full Moon	" 15,	8	32	P.M.	Full Moon	" 14,	5	55	A.M.
Last Quarter	" 22,	4	17	P.M.	Last Quarter	" 20,	9	26	P.M.
New Moon	" 29,	7	14	P.M.	New Moon	" 28,	8	31	A.M.

There will be an annular eclipse of the Sun on June 28th, which will be visible as a partial eclipse throughout the United States. The path of central eclipse begins in the Pacific Ocean, passes through Mexico and southern Florida, across the Atlantic, and ends in Africa. The annular eclipse of the Sun does not compare in interest to the total eclipse, as the disk of the Sun is at no time completely covered, and there is therefore no opportunity for study of the corona and other outer layers of the Sun's atmosphere, which do not come into good view except when the part of the Sun ordinarily visible is completely hidden by the Moon.

The Sun reaches the summer solstice and summer begins on June 21st, at noon, Pacific time.

Mercury passes superior conjunction and becomes an evening star on May 7th. It reaches greatest east elongation, 23° 59′, on June 7th, and reaches inferior conjunction on July 4th. From about the middle of May until after the middle of June it remains above the horizon more than an hour after sunset, and just about the time of greatest elongation, early in June, the interval is nearly two hours. For some weeks it may be seen in the evening twilight without difficulty. The number of days when the planet is visible is much greater than at average greatest elongations. The greatest elongation, 23° 59′, is somewhat above the average; but the planet comes to its aphelion about two weeks after, and this prolongs the period between greatest elongation and inferior conjunction. This interval is twenty-eight days, a long one as compared with the sixteen days at the previous appearance of the planet in February.

The relative motions of *Mars* and *Mercury* during June are interesting. *Mars* is moving rather steadily eastward and a little southward at the rate of about 42′ per day. At the

beginning of the month *Mercury* is about 4° west and north of *Mars*, and is moving in the same general direction, but at a considerably greater rate. It passes *Mars* on the morning of June 7th, the least distance between the planets being only 19′. But the speed of *Mercury* has been diminishing, and on the morning of June 17th *Mars* overtakes and passes *Mercury*. Between the two dates the planets are never much more than 1° apart. *Mercury's* eastward motion ceases on June 21st, and it then begins to retrograde. The same thing happens with *Mercury* and *Neptune*, the two planets being in conjunction twice, on June 10th and on June 30th.

Venus is an evening star and passed greatest east elongation on April 26th. On May 1st it remains above the horizon about four hours after sunset, nearly the maximum possible in our latitude. The interval diminishes, and on June 1st it is only three hours During June it diminishes with still greater rapidity, and at the end of the month it is only a little more than a quarter of an hour. The planet will reach inferior conjunction with the Sun on July 5th. During the whole period the planet will be very bright, the maximum being reached on May 29th, a time midway between the dates of greatest elongation and inferior conjunction. For some weeks before and after the time of greatest brightness the planet will be brilliant enough to be seen in full daylight. *Venus* is in conjunction with *Neptune* on the morning of May 21st, and with *Mars* on June 22d.

Mars is still an evening star, but the Sun is overtaking it in their common eastward motion, the distance between them diminishing from 37° to 18° during the two months' period. On May 1st it sets about three hours after sunset, and at the end of June only one hour after. It will not be easy to see toward the end of June, being so near the Sun, and also because it has nearly reached its minimum brightness. It will then be distant from the Earth about 240,000,000 miles, within 8,000,000 of the maximum distance.

Jupiter is still in good position for observation in the western sky in the evening. On May 1st it sets at about 1^h A.M., and on June 30th at about $9^h\ 30^m$ P.M. During the two months' period it moves from *Cancer* to the western part of *Leo*, about 10° eastward and southward, and on June 30th it is about 12° west and north of *Regulus*, the brightest star in *Leo*.

Saturn is now a morning star, rising at a little before 4^h A.M. on May 1st, and at about midnight on June 30th. It is rather too near the Sun to be at all conspicuous at the former date, but the distance grows greater rapidly, and it will soon be easy to see in the morning twilight. During May and June it moves 6° eastward and 2° northward in the constellation *Pisces*. During the spring months the Earth has been moving farther away from the plane of the rings, and the apparent minor axis has therefore been increasing, so that at the end of June it is about one seventh the major axis, and about one third of the diameter of the ball of the planet. A small telescope will now show the rings easily.

Uranus rises at about midnight on May 1st, and very shortly after sunset on June 30th. It remains in *Sagittarius* and moves about 2° westward in the two months' period. The nearest bright stars are the "milk-dipper" group, and the planet is about 5° north and east of the nearest one.

Neptune is in the western sky in the evening. It is in the constellation *Gemini*, and by the end of June has nearly reached conjunction with the Sun.

(SIXTY-THIRD) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to J. GRIGG, Esq., Thames, New Zealand, for his discovery of an unexpected comet on April 9, 1907.

Committee on the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, March 26, 1908.

(SIXTY-FOURTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. J. E. MELLISH, Madison, Wisconsin, for his discovery of an unexpected comet on October 13, 1907.

Committee on the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, March 26, 1908.

NOTES FROM PACIFIC COAST OBSERVATORIES.

On the Reseau.

In my paper on "The Distortions of Photographic Films on Glass"[1] appeared, as No. 6 in the summary of results, the following paragraph:—

6. If the results obtained in this investigation for small plates be found to apply with equal force to larger plates, it will follow that the assumption which is the basis for the use of the reseau is not well founded. The assumptions involved, briefly stated, are as follows: First, general distortions exist; second, they differ in different parts of the plate; third, they may be assumed to be linear within the squares of the reseau, i. e., over a stretch of 5^{mm} or more. The supposed advantages of the reseau over the method of referring all the measures to a common center rest entirely upon the validity of these three assumptions. If the reseau can be dispensed with there will be a saving of the labor involved in making the large number of settings on the reseau-lines and in the reductions of the measurements.

In regard to this paragraph, I have had an interesting correspondence with Mr. Hinks, chief assistant in the observatory of Cambridge University. The subject appears to Mr. Hinks and me to be of sufficient general interest to warrant the publication of the principal points that were brought out by the discussion. Mr Hinks agrees completely with my results on the nature and magnitude of the distortions in the gelatine film, the discussion being simply upon the question of the advisability of continuing to use the reseau, even though the original cause for its introduction has been shown to be non-existent. The present reason for continuing the use of the reseau is one of convenience purely. With the exception of a foot-note to Mr. Hinks's second letter, I shall confine myself to quotations from the correspondence.

S. Albrecht.

[1] An abstract of this paper was printed in *Publications of the A. S. P.*, Vol. XIX, p. 205, 1907.

Mr. HINKS's letter of August 16, 1907:—

Permit me to say that I have been much interested in your discussion of the distortion of the gelatine film in *L. O. Bulletin*, No. 118.

Your results for the absolute distortion are very much of the same order as those which I have found on my own plates, and I entirely agree with you that the general distortion is quite small as a rule. Your result that the treatment of the plates by various methods makes practically no difference is very interesting, valuable, and satisfactory.

With your last result, Summary § 6, I cannot however agree. It is true that the reseau was devised to eliminate distortion of the film, but it has proved itself so useful in other ways that it is still advisable to use it, even if it were absolutely certain that no distortion of the film exists. I would submit to you the following argument: If you do not use a reseau you must either use long screws or refer the measures to scales. Now long screws wear out quickly, are tedious to work with, have temperature errors, and so on. On the other hand, if you use divided scales you have to make as many settings as on the reseau, and you do so at great mechanical disadvantage. Therefore from a purely mechanical point of view I consider the reseau is the best.

Moreover it has in its favor one great practical advantage—there is no need to worry about the plate being disturbed during measurement it does not matter in the least. And if for any reason you suspect an error in the measures, it is the easiest thing possible to put back the plate and measure up that image in a couple of minutes

Here we have several people using the same measuring machine. We divide up the day roughly among us, but any man is at liberty to remove another man's plate if he finds the machine not actually at work and wants to use it himself. You can't do that unless you have a reseau, and it is the greatest possible convenience to be able to have this rough and ready rule.

. . . .

From my letter to Mr. HINKS, September 30, 1907:—

. . . In regard to the distortions we are in perfect accord. As to the reseau there seems to be some difference of opinion due, I believe, to an imperfect understanding of each other's method of measurement. Especially the following sentence I did not understand: "On the other hand, if you use divided scales you have to make as many settings as on the reseau, and you do so at great mechanical disadvantage." . . .

I agree with you that long screws are out of the question Metal scales also have a drawback. Glass scales, however, have a number of points in their favor, an important one of which is the fact that they have the same coefficient of expansion as the photographic plate Our Stackpole measuring machine has two glass scales, one for each coördinate, the distance between two successive rulings being 0.001 inch. The errors of the scale divisions have been carefully determined and are

practically negligible. In measuring, the frame, which carries the setting microscope and the two scale microscopes, is moved on slides parallel to the x and y coördinates (the x-slide is on this frame and carries the setting microscope and one of the scale microscopes) until the intersection of two fixed wires in the setting microscope falls over the center of the star image The scales are then read off directly in the scale microscopes, the interval between the nearest scale division and the fixed wire in the scale microscope being estimated to the nearest tenth. Thus no micrometers are used for making settings on the scale divisions One of the disadvantages of the Stackpole machine is that it is not tilted, so that a person must stand stooped over it while measuring In a differently designed machine this could be remedied, the scale microscopes could be more conveniently placed, and it might be an advantage to have the interval between scale divisions 0.01^{mm} instead of 0.001 inch ($0.025^{mm} \pm$).

As I understand it, for some unaccountable reason the reseau does not always reproduce itself exactly on the photographic plate, so that it is not entirely reliable where the greatest accuracy is desired . For somewhat more approximate [less accurate] measures I will grant that the reseau has the advantage of a slightly greater speed, in that you read off the distances to the reseau-lines in the same microscope that is used for setting on the star. When you want greater accuracy of measurement, you will probably have to use micrometers for measuring the distances to the reseau-lines. In our way of using the scales, the scale divisions from which we take our readings are always very close to the optical axis of the microscopes.

If for any reason you should wish to remeasure an image, the reseau certainly would allow it to be done quickly. As a matter of fact, however, the direct and reverse settings give a check to the measures, and this check is always made before removing the plate.

. . . .

From Mr HINKS's second letter, November 20, 1907 :—

. . . I shall try to put briefly my explanations of the way I look at the points mentioned in your letter.

1. Some misunderstanding was caused by my ignorance of the Stackpole machine, which I have never seen described I did not know that you *estimated* on ten scales to 0.0001 inch ($= 0.0025^{mm}$) I always supposed that you measurements went to a somewhat higher degree of *apparent* precision, which would almost necessitate your using microscopes to subdivide the scale On our machine we measure to 0.0005^{mm}; and though we can't swear to the last figure exactly, I think we can, on a good object, be accurate to within a probable error of about 1 unit in the last place I imagine that the p. e of one of your estimates is very much the same,—that is, one unit of *your* last place, which is bigger than ours ($\times 5$). Have you investigated your personal scale—i. e. preference for 5 over 4 or 6 for example? that is often a serious

reason why estimated last places should be in units as small as possible.[1]

2. The "mechanical disadvantage" to which I referred is involved in the fact that in your type of machine you depend upon perfect straightness of the main slides. If you use a *reseau* the slides may be practically as bad as they like.

3. The fact of uniformity of coefficient of expansion is a strong argument for glass over metal, but does not affect the question *Reseau or not*, as far as I can see.

4 The *reseau* does not reproduce itself exactly, but the so-called "errors of projection" are pretty constant. This means that you must study the division errors of the copies—and study so many that the distortion of the film in each goes out in the mean. This of course is tiresome But after all, the projection errors are not so large as the residual distortions of the gelatine you are prepared to admit. And as they are more nearly constant, and thus unimportant in much refined work such as stellar parallax, where absolute places are unimportant, I think the advantage still lies with the reseau.

5. . . . Optical distortion of the microscope does not come in if you work with a suitable objective of the first class. . . . A more frequent source of error in good machines is tilt of the scale in the eye-piece! But that is fortunately eliminated on reversal. . . .

Lectures at Berkeley.

The following course of lectures was given this term by members of the Lick Observatory staff before the class in Modern Astronomy at the University of California:—

Professor R. H. Tucker—Tuesday, March 24th, and Thursday, March 26th. Subject, "Meridian Circle Work."

Professor R. G. Aitken—Tuesday, March 31st; subject, "The Rings of *Saturn*." Thursday, April 2d; subject, "On Double Stars."

Professor C. D. Perrine—Tuesday, April 14th, and Thursday, April 16th. Subject, "The Lick Observatory Crocker Eclipse Expedition to Flint Island to Observe the Solar Eclipse of January 3, 1908." A. O. Leuschner.

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[1] With the Stackpole machine the probable error of a position, for a good object, does not exceed 0.00004 inch Our experience with this machine has shown that we can make the settings on good star images with greater accuracy than we can read the scales. It was for this reason that I suggested, in my letter, that the interval between scale divisions should be 0.01 mm instead of 0.025 mm. This would increase the accuracy of reading the scales two and a half times, which, for present purposes at least, would be entirely ample This also conserves the point, upon which we lay considerable stress, of making all our readings at the same point and very close to the optical axis of the microscope.—S. A.

REPORTS OF OBSERVATORIES.[1]

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

During the year 1907 Mr. D. SHELTON SWAN and the director of the observatory made observations of comets and of the planet *Eros*.

H. A. HOWE, *Director*.

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

Regular observation for the variation of latitude was continued throughout 1907, according to the programme assigned by the International Geodetic Association.

Doctor S. D. TOWNLEY was succeeded in charge September 1st by the writer. A comparison of over five hundred of the 835 separate determinations of the latitude made between June 13th and August 30th, about half by each observer, showed practically no difference of personal equation. The probable error of a single determination was found to be about 0″.10 for each observer.

The weather was in general favorable, till the later months of the year, when there was an abnormal prevalence of clouds The longest interval without observations was twelve nights, December 1st to 12th, due to almost continuous cloudy weather; there were two intervals of seven days, due to unfavorable weather, in the first quarter of the year.

The following table gives a summary of the observations for the variation of latitude. The columns contain, respectively, the number of determinations made each month, the number of nights on which observations were made, the number of complete nights (sixteen determinations), and the greatest interval in each month during which no measures were obtained:—

[1] Arranged alphabetically according to name.

1907.	Pairs.	Nights.	Nights.	Nights.
January	152	11	7	6
February	158	12	8	7
March	147	12	7	7
April	209	15	10	4
May	180	15	10	5
June	231	17	13	4
July	356	24	20	2
August	303	21	13	2
September	178	13	5	3
October	146	12	2	5
November	167	12	5	6
December	68	5	1	12
Totals 2,295		169	101	
Means	191	14	8 +	5 +

Seven determinations of the constants of the zenith telescope, well distributed in time, indicate very satisfactory stability throughout the year.

JAMES D. MADDRILL,
Astronomer-in-Charge.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

(The report will be printed in the next number of the *Publications.*)

LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA.

The work of the observatory for the past year includes: (1) Visual and photographic observations of the planets *Venus, Mars, Jupiter,* and *Saturn;* (2) The visual and photographic observations on *Mars* made by the South American expedition; (3) Spectrographic work on the planets with especial reference to the lower red end of the spectra for investigations on atmospheric absorption effects; studies in detail of the spectrum of *Mars* and of different parts of the disk of *Jupiter;* (4) Radial velocity determinations of a selected list of stars; (5) Charting of star-fields along the ecliptic with the Brashear doublet, and the discovery of eleven new asteroids, the determination of their positions as well as the positions of a large number of known asteroids; (6) Micrometric measures of double stars; (7) Many laboratory visual experiments with reference to testing the validity of certain visual observations

on the planets; (8) Photographic experiments with regard to applications in planetary photography and the photography of spectra; (9) Work on the improvement of methods and equipment for use in planetary photography. A more detailed account of the above follows.

Visual observations on *Mars* were begun here on March 22d and continued until January, 1908 The opposition of the planet just past was one of the so-called favorable ones. The great southern declination of the planet, however, rendered it difficult for most observatories in the northern hemisphere. The more southern latitude of Flagstaff was here to its advantage. In spite of the low altitude of the planet, the outcome of the observations there, both visual and photographic, were very successful. The two most important results were (1) the observations on the two polar caps at their simultaneous maximum and minimum states respectively, their subsequent careers, and the addition to the knowledge of them in consequence; and, (2) the detection of a canal system connecting with the south polar cap analogous to that already detected for the northern. This was an especially telling contribution, as it confirmed the theory of the office and behavior of the canals previously advanced here.

At the suggestion of Professor TODD, the Director decided to send an expedition to South America in his charge, and Mr. E. C. SLIPHER was detailed by the Director for the *Mars* work. Planetary camera, amplifying lenses, color filters, and plates were made for him, the duplicates of those used in the work at Flagstaff. The party sailed from New York on May 11th, and arrived at Iquique, Chili, June 14th. The observing station selected, Alanza, was about sixty miles inland southeast from Iquique, in the desert Tarapaca, at an altitude of about four thousand feet. The excellent quality of both photographs and drawings shows that the expedition was very fortunate in finding at the first trial a locality with conditions so favorable for their work. Much credit is due to all the members of the expedition for the part they contributed to making the undertaking a success, and especially must great praise be given to Mr. SLIPHER for his part in the work. All the *Mars* observations were made by him, and the excellent series of drawings and photographs he returned with testified to his ability and industry in carrying out the programme of work planned.

Mention must also be made of the efficient assistance rendered him by Mr. A. G. ILSE, who was kindly detailed by the Alvan Clark & Sons Corporation to be the mechanician of the expedition.

The photography of *Mars* was begun at Flagstaff on June 3d and continued until September 2d. Photographs were made by Mr. LAMPLAND and the Director, and in all a little over five thousand images were made. At the South American station, photographs were made by Mr. SLIPHER from June 24th until August 1st. Actual count since his return shows that he had made over 13,300 exposures. The South American photographs are, on the whole, superior, though a large per cent of the images of both series have excellent definition. In 1907 the larger and brighter disk of the planet, more efficient camera equipment devised by Mr. LAMPLAND, and the value of experience in the work, all contributed to obtaining better photographs than those made during the opposition of 1905. The length of time covered by the present series and the uniformly good quality of the images make them of great value, not only as a corroboration of the drawings, but also for study independent of the visual results. The photographs show an amount of delicate detail that is truly remarkable, and their importance and value in the advancement of Martian study can best be fully appreciated by any one who has spent much time and care in charting visually the difficult detail of the planet. Detail that taxed vision to the utmost, especially markings in regions lacking in or having slight differences of contrast, could sometimes be seen with ease in the negatives made at the same time. These results bring out well the efficiency of the photographic plate, with suitable exposure and development, in registering delicate detail and small variations in contrast. Generally the photographs bring out the detail in the dark regions better, compared with the appearance of the planet visually, than in the light regions, and the negative here seems to be superior to the eye in detecting small differences of contrast. Of course, for form, fineness, or linearity, the eye is first. Some idea of the delicacy of the detail photographed may be gathered from the fact that the twin canals Gihon and Euphrates were shown double in many of the images, made at different dates, of both the South American and the Flagstaff photographs.

The series of measures by Mr. LAMPLAND and the Director, for the determination of the position of the axis of *Mars* and the eccentricity of the south polar cap, have been reduced and entirely confirm the lesser obliquity of the Martian ecliptic, found from the earlier Flagstaff measures, 1901-1905. (See *Lowell Observatory Bulletin*, Nos. 9 and 24.) This shows that the change in the obliquity suggested by the writer, and now incorporated in the ephemeris of the "British Nautical Almanac," was in the right direction.

Observations on *Venus* were made by the Director during the summer months, confirming his detection of the markings upon it in 1896-7 and 1903, and have been continued by Mr. E. C. SLIPHER since November.

Jupiter was observed during April and May. A good series of drawings and a number of photographs were made. The wisps crossing the equatorial belt, so well shown in the drawings of Mr. SCRIVEN BOLTON, of England, were easily seen, and also confirmed by photographs.

Observations were made on *Saturn* in June and from the first of November until January. A little before sunrise on June 19th, a new phenomenon was detected here in the ring system. The most conspicuous feature of the disk at the time was the dark band, the shadow of the rings, which then belted the planet's equator. The shadow, far from being dark, was only moderately dusky, and furthermore presented, when first looked at, a curious tripartite appearance. On more careful scrutiny its lack of uniformity proved to be due to a narrow black line that threaded it medially throughout its length, the black core being perhaps one fourth as wide as the less dense background upon which it stood. At the same time, the rings themselves could with attention be made out as the finest knife-edges of light cutting the blue of space on either side of the planet's disk. The planet was not looked at again until October 31st, other work occupying the observatory in the meantime. In November, however, it was critically studied. The dusky band was evident, as in June, and the black line made core to it, as before. This black medial line was by no means even; it both undulated slightly and showed irregularities of outline, one black bead in especial being noticeable upon it about half way from the planet's center to its (the

planet's) eastern limb. (November 13, 7^h, M. S. T.) The line also seemed not quite central in the belt, but a little nearer its northern edge. In November the rings were easily seen, although, as before, only the edge of their plane was presented to the eye. But in addition to the general line of their light, agglomerations were plainly discernible on them. A number of measures of the agglomerations and the core of the shadow-band were made in November and December. During the last part of December the agglomerations were too faint for measurement, and were last seen by Mr. LAMPLAND on December 31st. The rings were glimpsed by him on January 3d and 4th, but were then so faint that he was unable to see if irregularities were still present. Unfavorable conditions prevented observations until January 7th, when the rings were easily seen and found to be perfectly continuous. An investigation by the writer, explaining the core of the shadow band and the agglomerations in the ansæ of the rings, has been published in detail elsewhere. A brief statement of the results of this study may be of interest here. The investigation brings out the interesting fact that the particles composing the ring-system cannot all be situated in one plane—that the rings are not flat rings but tores, rings after the manner of anchor-rings, encircling the planet. This out-of-planeness of the particles is easily seen, applying the methods of celestial mechanics, to be a consequence of the perturbing influence of the nearer satellites and the mutual impacts of the particles of the rings. In support of this view, we find that micrometric measures place the agglomerations where we should expect to find them from theoretical considerations. The black core of the shadow-band leads to a like conclusion: that in the black core we are looking at such parts of the ring-system as are practically plane, chiefly ring *A*, and in the dusky shadow about it through particles, situated above and below that plane, lying in the other rings.

The spectrographic work done during the year has been confined principally to studies of the red end of the spectra of the planets, and the radial velocity determinations of a selected list of stars. With greatly improved red-sensitive plates, perfected by his extensive experiments with sensitizing dyes, Mr. SLIPHER has been able to photograph many hitherto unknown absorption bands and lines in the spectra of the major planets.

The lower red end of the spectra of the other planets and many stars are almost as interesting as those of the major planets. Of the new bands discovered in the spectra of the major planets, the strongest is found near λ 7200. This band in *Jupiter* and *Saturn* is far stronger than the characteristic one at λ 6190. A series of plates of the spectra of *Mars* and the Moon, photographed at equal altitudes, and under favorable conditions, on nights selected on account of their advantageous meteorological state, shows this band to be reinforced in the spectrum of *Mars*. The band λ 7200 coincides in position and appearance with the "a" group of the telluric spectrum which ROWLAND and JEWELL found to be due to water vapor. The *D* band is likewise broadened relatively with *Mars* spectra, indicating enforcement of the water-vapor lines there.

A study has been made of the spectrum from different parts of the disk of *Jupiter*, revealing interesting differences.

The results of these spectrographic studies will be published in the near future.

A good deal of attention has been given to the problem of planetary photography, with a view to devising more efficient methods and equipment for that work. The planetary camera was rebuilt, according to designs by Mr. LAMPLAND, during January and February, by WM. GAERTNER & Co., of Chicago. In planetary photography, with a visual refractor, good color screens form a very important part of the equipment, and every effort has been made to obtain the best ones that could be made. Both solid (stained film of gelatine between plates of optical glass) and liquid (glass cell with plane-parallel walls containing the absorbing solution) filters have been used. Mr. R. J. WALLACE made three more solid filters, and adjusted the absorbing solution for two liquid-filter cells. The optical parts for the liquid filters were made by Mr. O. L. PETITDIDIER, and were figured accurately plane. The absorption values of two of the solid filters and of one of the solutions for the liquid filters were adjusted by Mr. WALLACE according to specifications based on investigations by the writer. Mr. SLIPHER'S remarkable success in his experiments in sensitizing plates, with comparatively even sensitiveness for a long range of the spectrum extending far into the red, suggested that his plates might be used with good results in planetary photography in

connection with a suitable color-screen, by which more perfect monochromatization relatively to the amount of light forming the image might be attained. Tests of the plates in the photography of the planet brought out that they lacked the quality of delicate gradation so important in this work. Later tests of the new filter, using Cramer's isochromatic plates, showed that it gave definition superior to the filters formerly used, though requiring a little longer exposure to give the same density of image It proved indeed to have been previously made for use with these plates, though not for planetary photography. The investigation on the filters, giving a statement of the principles involved and the results of the experiments, will be found in *Lowell Observatory Bulletin*, No. 31.

Experiments were made with commercial photographic lenses (ZEISS and COOKE) for amplifying lenses in the planetary photography, but these were not found to perform as well as the new negative lens made by MR. LUNDIN, of the Alvan Clark & Sons Corporation.

In the laboratory visual experiments performed, in connection with investigations on *Mars*, efforts have been made to carry them out under conditions as nearly like those found in actual observational work as possible. The 24-inch, 6-inch, and 4-inch telescopes, with different magnifications, have been used in the experiments. By varying the different factors, optical systems, apertures, and magnifications, and "seeing" (atmospheric disturbances) conditions existing in observing, work can be approximated quite satisfactorily. For instance, the effect of atmospheric disturbances can be obtained by selecting certain moments for the observations, or by varying the length of the air-path, or the magnification. At the same time, one can of course vary the dimensions of the objects observed until they have the required angular dimensions. The optical systems and general conditions being about the same as in actual observing work, conclusions can more safely be drawn from the experimental work.

Other additions to the equipment than those already mentioned were, a new device for illumination of the field and improved electric illumination of the micrometer of the 24-inch telescope, and a large observing chair of the same pattern as the one used at the Ladd Observatory.

PERCIVAL LOWELL, *Director*.

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

During the past year the work of this observatory has been about the same as in past years. The number of chronometers rated and issued to ships has, however, somewhat increased, owing to the increased naval activities in the Pacific. The time service has continued as heretofore, and wireless messages have been installed for giving the time to the fleet at Magdalena Bay, Lower California. These messages cannot be sent great distances by day, and at present are delivered on Mondays and Thursdays of each week, at 9 o'clock at night. This service has proved satisfactory. In some cases messages have been delivered to ships near Honolulu, at a distance of fifteen hundred miles from the transmitting station.

In addition to the routine work of the observatory as regularly carried on, the officer in charge has continued his researches on "The Cause of Earthquakes and Mountain Formation." Three papers on this subject have been published in the *Proceedings* of the American Philosophical Society at Philadelphia. The new theory, that these disturbances are due to the secular leakage of the ocean bottoms, may now be regarded as proved. The subject thus opened up, however, is still so unexplored that a fourth paper is to be added to those already published, in order to render the theory more complete.

Recently the officer in charge has taken up a general revision of the orbits of double stars. Ten orbits, mostly of new pairs, have recently been communicated to the Royal Astronomical Society in London. The earthquake researches, which proved so fruitful of discovery in the domain of the physics of the Earth, were the natural outcome of the previous work on the internal constitution of the Sun and planets carried out here in 1904 and 1905, and published in the *Astronomische Nachrichten*. When the great earthquake occurred it was felt to be a public duty to seek out the cause of such disturbances, in the hope of ascertaining the relative safety of California. This region is now shown to be much less endangered than most regions about the Pacific Ocean.

T. J. J. SEE,
Professor of Mathematics, U. S. Navy,
in charge of the Observatory.

SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, MT. WILSON, CALIFORNIA.

The investigations in progress during the past year include:

1. Daily photography of the Sun with the photoheliograph.
2. Daily photography of the Sun with the spectroheliograph.
3. Photography of the spectra of sun-spots.
4. Photographic comparisons of the spectra of various parts of the Sun's disk.
5. Spectrographic investigations of the solar rotation.
6. Laboratory investigations.
7. Pyrheliometric observations.

Direct photographs of the Sun have been made daily with the Snow telescope, by Mr. ELLERMAN or Mr. OLMSTED. These negatives are used mainly for comparison with spectroheliograph plates.

The daily series of photographs made by Mr. ELLERMAN or Mr. OLMSTED, with the 5-foot spectroheliograph and Snow telescope, comprises negatives made in the early morning and late afternoon, with the lines of calcium, hydrogen, and iron. The hydrogen line regularly employed is $H\delta$. We have recently discovered, however, that the $H\alpha$ line gives results differing very decidedly from those obtained with $H\delta$. The high sensitiveness for red light imparted to photographic plates by bathing them in a three-dye solution, devised by Mr WALLACE, of the Yerkes Observatory, permits excellent photographs to be made with the $H\alpha$ line, in spite of the comparatively low dispersion in the red of the 5-foot spectroheliograph, and the consequent necessity of using a very narrow camera slit Hereafter $H\alpha$ plates will be taken regularly, since the bright flocculi which they bring out are sometimes, if not invariably, absent from the $H\delta$ plates. There also seem to be interesting differences in the forms of the dark flocculi shown by the two lines These results have only just been obtained, and it has not yet been possible to ascertain the causes which produce the interesting and striking differences revealed by the photographs.

The 30-foot spectroheliograph of the tower telescope is under construction and should be in use within a few months.

Some experiments have been made, however, with the 30-foot Littrow spectrograph of the tower telescope used as a spectroheliograph. The 12-inch object-glass, of sixty feet focal length, of this telescope, is mounted in a carriage and connected with an electric motor in such a way that it can be moved at a uniform rate in an east-and-west direction. This causes the image of the Sun, formed in a house at the base of the tower, to move across the collimator slit of the spectrograph. Most of the work has been done in the second-order spectrum of a 4-inch plane grating, which is not nearly large enough for the full aperture (six inches) of the spectrograph, but is nevertheless better suited for this purpose than any other grating in our possession. The spectroheliograph attachment consists of a plate-carrier movable on steel balls across two adjustable slits. This apparatus is mounted on the spectrograph in the position usually occupied by the plate-holder employed for photographing spectra. The two slits are made to coincide with any two lines of the spectrum, and the photographic plate is moved over them at the same rate as the solar image—by means of the same motor. In this way monochromatic images of limited regions of the Sun can be photographed simultaneously with two of the Fraunhofer lines. With this apparatus the peculiarities of the $H\alpha$ lines were discovered. Experiments are now in progress with other dark lines. A special attempt will be made with this instrument, and with the permanent 30-foot spectroheliograph, to determine whether anomalous dispersion phenomena are exhibited by the flocculi.

The photographic study of the spectra of sun-spots, which was mentioned in the last annual report, has been continued and extended through the advantages afforded by the new tower telescope. The negatives of spot spectra made with the 18-foot Littrow spectrograph and Snow telescope have been used for a preliminary photographic map of the spot spectrum, extending from λ 4600 to λ 7200. The map consists of twenty-six strips, each including one hundred Ångstroms, and is provided with a solar spectrum for comparison purposes and an approximate scale to aid in the identification of spot lines. At the recent Paris meeting of the International Union for Coöperation in Solar Research this map was adopted for the use of the coöperating observers. Each visual observer has

selected a certain limited region of the spot spectrum, in which he compares the lines, as seen at the telescope, with those recorded on the map. In this way any changes in the relative intensities of the lines, if such occur, can be readily detected. Copies of the map have been placed in the hands of all observers who are taking part in this work of the Solar Union

A preliminary catalogue of the lines affected in sun-spots is being prepared by Mr. ADAMS and myself, with the assistance of Miss BURWELL, of the Computing Division. The first installment of this catalogue, prepared by Mr. ADAMS, covers the region λ 4000 to λ 4500, and contains about 875 lines. The publication of the second portion of the catalogue, covering the region from λ 4500 to λ 5000, has been delayed by the fact that the photographs of spot spectra, made with the 30-foot spectrograph and the tower telescope, show many more lines than our previous photographs. These plates are therefore being used in preference to the earlier ones in preparing the catalogue. They will also serve to give a definitive map of the spot spectrum on a scale of 4^{mm} to an Ångström. Special apparatus for enlarging and widening the spectra for this map is now under construction and will soon be ready for use.

The hypothesis that the relative intensities of the spot lines are due to reduced temperature has received further confirmation during the year, especially through the identification in the spot spectrum of many bands due to compounds This work is referred to below in connection with other laboratory investigations.

A photographic study of the spectra of various parts of the Sun, made by Mr ADAMS and myself, has shown that marked differences distinguish the spectrum of the center from that of points very near the limb. The Fraunhofer lines not only undergo changes of intensity, similar to those observed in the case of sun-spots, but they are also shifted in many instances from their normal positions. Since the lines of the cyanogen flutings are not shifted, and since the relative displacements of various metallic lines correspond fairly well with their displacements produced by pressure in the laboratory, it seems probable that the changes in line positions are due to an increase of effective pressure near the limb. Such a conclusion would be in agreement with the views of HALM. How-

ever, a continuation of the solar work, which already covers a large range of the spectrum, and a number of laboratory investigations will be required to settle the question definitely. It seems probable that the observed phenomena, which include several not mentioned above, such as the marked reduction in intensity of winged lines at the limb, are due to a combination of several causes, of which increased pressure may be one.

Mr. ADAMS's spectrographic investigation of the solar rotation, which was begun with the Snow telescope and 18-foot Littrow spectrograph, have been continued with the tower telescope and 30-foot spectrograph. The following table contains the results published in *Contributions from the Solar Observatory*, No. 20:—

ϕ	Weight.	v km.	ξ	Period. Days.
0° 2	21	2.078	14°.75	24 39
7 .7	15	2.023	14 .50	24.83
15 .0	23	1 957	14 .39	25.01
22 .7	13	1.808	13 .92	25.86
29 .7	24	1.673	13 .68	26.32
37 7	15	1 461	13 .11	27.46
44 .7	23	1.279	12 .77	28.19
52 7	18	1 055	12 .35	29.15
59 .6	24	0 864	12 .13	29.68
65 .7	20	0.696	11 .99	30.02
74 9	33	0.434	11 .85	30 38
80 .4	11	0.277	11 .84	30.40

The more important conclusions derived from this investigation may be summarized as follows:—

(1) The period of rotation agrees closely with that of DUNÉR as far as latitude 50°. In higher latitudes it is considerably shorter. It does not agree with either of the determinations of HALM, but coincides well with their mean.

(2) Different lines give slightly different rotation periods Of the elements investigated carbon and lanthanum give the longest periods. At the equator this difference amounts to about 0°.1 in the daily angular motion.

(3) No appreciable change in the rotation period has been found during the fourteen months covered by the observations.

(4) The photographic method gives results for individual lines of slightly higher accuracy than the visual, if we may judge from a comparison of the probable errors. The greatest advantage it possesses, however, is the opportunity it affords for the inclusion of many more lines than would be possible with visual measures.

The extension of this work to include the hydrogen lines has led to the important results summarized in the following table:—

ϕ	$v+v-$	ξ	Period, Days.
$-0°.1$	2.21^{km}	$15°.7$	22.9
9 .3	2.15	15 .5	23.2
14 .8	2.10	15 .4	23.4
22 .7	2.03	15 .6	23.1
29 .7	1.87	15 .3	23.5
44 .5	1.55	15 .4	23.4
59 .3	1.12	15 .6	23.1
73 .5	0.67	16 .7	21.6

From these results it appears that the hydrogen whose speed is measured with the spectrograph does not follow the same law of rotation as the spots. The daily motion of the hydrogen is much greater than that of the spots at the equator, and has about the same values in high and in low latitudes. Similar results obtained from the motions of the hydrogen flocculi are described below. The spectrographic work is being continued, and other lines will be included for measurement.

As the development of our solar investigations has been hampered by the meager information available on the spectra of the elements under various conditions of temperature, pressure, etc., an important extension of our laboratory work has been rendered necessary. In order that we may be in a position to make a suitable study of anomalous dispersion phenomena, and to continue the investigation described in my last report on the cause of the characteristic phenomena of sun-spot spectra, a powerful electric furnace was required. Other apparatus, demanding much heavier electric current than could easily be generated on Mt. Wilson, was also essential

For this reason it was decided to build a small laboratory in Pasadena, where unlimited current can be obtained from the Edison Electric Company at moderate cost. This laboratory is now completed, and Dr. ARTHUR S. KING, formerly of the University of California, has been placed in charge of it.

Prior to the construction of the new laboratory practically all of the physical work was done on Mt Wilson. Dr. OLMSTED'S investigations in this department during the year included an attempt to identify unknown bands in sun-spot spectra and a photographic investigation of the relation between the nature of the discharge of an electric arc and the relative intensities of its spectral lines. Some of the bands of titanium oxide were identified by Mr. ADAMS last year in our photographs of spot spectra, and subsequently Professor FOWLER found certain other bands in our map of the spot spectrum to be due to magnesium hydride. To these Mr. OLMSTED has added some bands observed in a calcium arc burning in an atmosphere of hydrogen. He has also made, with the 30-foot spectrograph of the tower telescope, a series of photographs covering the whole visible spectrum of titanium oxide These plates are crowded with thousands of lines, many of which have not yet been identified in the spots

The duties of the Smithsonian Astrophysical Observatory in Washington prevented the continuation of the Smithsonian Expedition's work on Mt. Wilson during the summer of 1907. At Mr. ABBOT'S request, however, a pyrheliometer was used by Mr. OLMSTED on many days during the year, for the purpose of determining the solar constant, on the assumption that the correction derived from the Smithsonian Expedition's observations in 1905 1906 can be applied to these results This assumption is presumably valid, for it appears from Mr. ABBOT'S discussion of the bolometric results for 1906 that they can be duplicated from pyrheliometric and relative humidity observations, with an average deviation for a single observation of 1.5 per cent.

The results of the important work done on Mt Wilson, under the direction of Mr ABBOT, in 1905 and 1906, have been published in Volume II of the *Annals of the Smithsonian Astrophysical Observatory*. This work will be continued here during the summer of 1908.

Professor JULIUS, of the University of Utrecht, spent several weeks on Mt. Wilson last summer, for the purpose of carrying on certain investigations on the phenomena of anomalous dispersion. These were made with an electric furnace, the 5 foot spectroheliograph being employed to photograph the phenomena produced in a tube of sodium vapor by slight changes of density caused by local cooling. These phenomena resemble, in some respects, those of the solar flocculi, which Professor JULIUS ascribes to anomalous ray-curving in the Sun. A symmetrical illumination, similar to that employed in these experiments, may be secured near a sun-spot, from the edge of which photospheric light reaches us after transmission through calcium and other vapors where density gradients doubtless exist. It should be possible to learn whether the H flocculi are the effects of anomalous dispersion by photographing a spot group with the camera-slit set on H_1. If photographs of the same group are taken simultaneously with the same spectroheliograph, having a second camera-slit set on the continuous spectrum, the distance between the edges of two spots should, in general, differ in the photographs. If any differences exist, they should increase as the camera-slit is set nearer H_1. Furthermore, photographs made with the camera slit set on opposite sides of H_1, should give differences in the form and appearance of the flocculi. It is hoped that these tests can soon be made with the tower telescope and 30-foot spectroheliograph. Many other investigations will be made with the hope of determining conclusively what part, if any, anomalous dispersion plays in solar physics

The work of the Computing Division, under the direction of Mr. ADAMS, has progressed very satisfactorily during the year. Miss WARE has devoted all of her time to the measurement of the heliographic positions of flocculi with the heliomicrometer, for the purpose of determining the solar rotation. The measurement of the calcium (H_2) flocculi is not yet completed, but the preliminary results given by 1680 flocculi on fifty-one plates are shown in the following table:—

Latitude	Calcium (H) No. Points.	Flocculi ξ	Hydrogen ($H\delta$) No. Points.	Flocculi ξ
0° ± 5°	232	14.5	91	14.3
5 ± 10	202	14.3	77	14.4
10 ± 15	317	14.3	95	14.6
15 ± 20	326	14.2	73	14.5
20 ± 25	259	14.2	71	14.7
25 ± 30	153	14.0	65	14.7
30 ± 35	99	13.8	33	14.9
35 ± 40	26	14.0	23	14.6
40 ± 45	6	13.2	19	14.4

In this table are also given a preliminary determination of the mean daily motions of the dark hydrogen ($H\delta$) flocculi, as derived from the measurement of 547 flocculi on twenty different plates. On account of the large proper motions and rapid changes of form of the hydrogen flocculi, their mean daily motions cannot be determined with as great precision as is possible in the case of calcium. However, it will be seen that the results in the table give no evidence of a systematic variation of the rotation with the latitude, such as is observed in the case of sun-spots, and also in that of the calcium flocculi. Since, as has already been pointed out, Mr. Adams's spectrographic work also shows that hydrogen moves at approximately the same angular velocity in all heliographic latitudes, it is evident that the well known law of equatorial acceleration does not hold for all classes of solar phenomena. The speed of the hydrogen measured spectrographically is considerably greater than that of the flocculi. Many more measures, however, will be required to give the motion of the flocculi with sufficient precision for satisfactory comparisons. It now remains to be determined whether their comparatively slow motion is due to the fact that the hydrogen in the flocculi rises from lower levels and retains the smaller velocities prevalent there, or, as seems more likely, that the hydrogen lines whose displacements are observed at the Sun's limb are due mainly to absorption at a level above that of the dark $H\delta$ flocculi. The recent work on the $H\alpha$ flocculi, referred to at the opening of this report, is not unlikely to throw some light on this question.

Miss SMITH is now concluding the reduction of a large number of measures of the areas of the calcium flocculi lying in squares 10° on a side within an area extending 40° in latitude and 40° in longitude from the Sun's center These results are expected to give a valuable measure of the total solar activity, and to indicate its fluctuations in different parts of the Sun.

Miss LASBY has devoted most of her time to the measurement of photographs taken by Mr. ADAMS for the spectrographic determination of the solar rotation. She has also measured a number of photographs of spectra corresponding to the center of the Sun and to points near the limb

Miss BURWELL has been engaged in the study of photographs of spot spectra, measuring the positions of unknown lines, and estimating the intensities of the lines which differ from those of the solar spectrum.

Miss WICKHAM, who has recently joined the Computing Division, is occupied with the measurement of metallic spectra.

The work of the Construction Division, which has been continued under the superintendence of Mr. RITCHEY, has included the optical and mechanical work on the 60-inch reflector; the construction of two mirrors and many of the mechanical parts of the new tower telescope, and its erection upon Mt Wilson; the completion of the Mt. Wilson Road, and the transportation of materials to the summit of the mountain; the erection of the steel building and dome for the 60-inch reflector; the construction of the Hooker Building and the new spectroscopic laboratory in Pasadena, and miscellaneous work on minor instruments.

All of the optical work for the 60 inch reflector, except the final figuring of the two small convex mirrors, has been completed by Mr. RITCHEY. The mounting is now being assembled for the last time, preparatory to sending it up the mountain. It is hoped that this can be done early in June, soon after the mountain road has been put in repair. This road was completed in May, 1907, and more than 150 tons of steel, for the building and dome of the 60-inch reflector, were hauled over it before the beginning of the present rainy season. The road has not been greatly damaged by the recent storms, and can soon be put in condition for the heavy demands of

next summer's work. The skeleton of the steel building and dome has been erected on Mt. Wilson, but the completion of the riveting and the work connected with the shutter, driving mechanism, observing platform, wind-screen, etc., cannot be completed for several months. It had been hoped that all of this work could be finished last year, but labor troubles and strikes at the Union Iron Works, and other unexpected difficulties, caused unforseen delays.

The new tower telescope erected last autumn has already been described in these *Publications*. It has proved to be an extremely satisfactory instrument, especially in combination with the 30-foot spectrograph. The excellent definition obtained with this telescope, and the fact that the mirrors are not distorted by sunlight, has already permitted several investigations to be made which could not be carried out with the Snow telescope.

Work on the 4.5-ton glass disk for the 100-inch reflector is still in progress at St. Gobain, France. Meanwhile, in view of Mr. HOOKER's desire that the necessary arrangements for grinding and figuring be made before the disk reaches us, a building has been erected for the optical work, and the large grinding machine is now approaching completion. In addition to a grinding room and testing hall, the new Hooker Building contains rooms for grinding and polishing tools, a fireproof storage vault for astrophysical negatives, and a series of computing offices. It thus forms a most valuable addition to our resources in Pasadena. Mr. RITCHEY is at work on preliminary designs for the 100-inch mounting, but no attempt will be made to complete these before the 60-inch mounting has been thoroughly tested.

GEORGE E. HALE, *Director*.

STUDENTS' OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

During the past year, as heretofore, the chief work of the Berkeley Astronomical Department of the University of California has been in the line of instruction The number of enrollments in the department and the demand for additional courses increases steadily from year to year. The number of students enrolled in astronomical courses for the current aca-

demic year now exceeds four hundred as against two hundred and sixteen in 1905-1906. The teaching force has been increased by the appointment of Mr. W. F. MEYER, a graduate of Drake University. The usual course of six lectures offered by the Lick Observatory staff in connection with the course in Modern Astronomy has proved a most instructive and profitable feature of the opportunities offered to the general student body. Eight graduate students, who are looking forward to the degree of Doctor of Philosophy, were enrolled in the Lick and Berkeley astronomical departments at the close of the year 1907.

The work of investigating the perturbations of the minor planets discovered by JAMES C. WATSON was continued during the past year as heretofore. It is now over six years since this investigation was undertaken in the department. No one not familiar with the details of this work can form an adequate idea of the theoretical and practical difficulties which have been encountered. The present condition of the Watson work is as follows:—

1. Tables are being printed of the following twelve planets:—

(93) *Minerva.*	(105) *Artemis.*	(139) *Juewa.*
(101) *Helena.*	(115) *Thyra.*	(161) *Athor.*
(103) *Hera.*	(128) *Nemesis.*	(174) *Phædra.*
(119) *Althæa.*	(133) *Cyrene*	(179) *Klytæmnestra.*

2 The perturbations are developed, the observations collected, and the elements corrected for the following five planets:—

(94) *Aurora.*	(104) *Clymene.*	(150) *Nuwa.*
(100) *Hekate.*	(121) *Hermione.*	

A second correction of the elements is necessary. The principal perturbations of the second order may have to be computed for some of these planets.

3 The perturbations are developed for one planet:—

(79) *Eurynome.*

4. *Three* planets belong to the group ½, and special tables for this group have been computed after BOHLIN. A comparison of these tables with similar tables by VON ZEIPEL needs to be made before developing the perturbations The original

programme for these planets may be changed by adopting the Gyldén-Brendel-Kramer method. These planets are:—

(106) *Dione*. (168) *Sybilla*. (175) *Andromache*.

5. One planet, (132) *Æthra*, is lost. Computations are under way to decide its fate.

Total number of planets = 22.

Of the twelve planets for which the tables are completed and in press, comparison has been made of recent subsequent observations with the tables with eminently satisfactory results, except in the case of (115) *Thyra*, which was in opposition in May and for which observations have not as yet become known, although an ephemeris was published in *Lick Observatory Bulletin*, No. 114. The average interval which has elapsed between the last observation used in the correction of the elements and perturbations on which the tables are based has been from six to seven years. Some of these observations have been especially secured at the Lick Observatory and at the U. S. Naval Observatory for the purpose of testing the tables. The numerical part of the work will now be interrupted temporarily, mainly for the purpose of enabling Professor LEUSCHNER to prepare a definite programme for the completion of the tables of the remaining ten planets. At least one half of the computations necessary on these planets are completed. It is estimated that upon resumption of the computations the work of two computers for one year will be required for completing the Watson work inclusively of constructing the necessary tables. Among the practical difficulties encountered were those due to erroneous identifications of minor planets. Observers ought to realize that the opposition positions given in the *Jahrbuch* do not, in general, take account of the perturbations, which in some cases affect the geocentric positions by many degrees, and that not infrequently more than one planet occupies nearly the same position in the sky.

All other activities of the observatory referred to in former reports, such as seismological and meteorological observations and occasional astronomical observations, have also been continued during the past year, and minor contributions have been made to astronomical journals.

In connection with the work of the State Earthquake Investigation Commission, the Director has prepared a complete

catalogue of all after-shocks observed in California up to June 10, 1907. This catalogue is being printed by the Carnegie Institution in the forthcoming report of the California State Earthquake Commission.

In connection with the courses in theoretical astronomy, Professor CRAWFORD has published a number of comet orbits jointly with members of his classes. These are. Elliptic Elements and Ephemerides of Comet *h* 1906 (METCALF), *L. O. Bulletin*, No. 108; Elements and Ephemeris of Comet *a* 1907 (GIACOBINI), *L. O. Bulletin*, No. 111; Second Elements and Ephemeris of Comet *a* 1907 (GIACOBINI), *L. O. Bulletin*, No. 113; Elements and Ephemeris of Comet *c* 1907 (GIACOBINI), *L. O. Bulletin*, No. 116; Elements and Ephemeris of Comet *d* 1907 (DANIEL), *L. O. Bulletin*, No. 119; Elements and Ephemeris of Comet *e* 1907 (MELLISH), *L. O. Bulletin*, No. 121; Second Elements and Ephemeris of Comet *e* 1907 (MELLISH), *L. O. Bulletin*, No. 124.

A. O. LEUSCHNER, *Director.*

BERKELEY, CAL., April 3, 1908.

GENERAL NOTES.

Drifts of Stars.—At the February meeting of the British Astronomical Association, an instrument was exhibited which illustrated in a beautiful and striking manner the validity of the error curve. "The apparatus was a box with a glass front, at the bottom of which were a number of receivers of equal size, while above were a large number of pins stuck in the back of the case. It was shown how, by pouring in a quantity of millet seed [through a single orifice at the top], the seeds jumped from one pin to another, but in the long run so arranged themselves as to form always the same curve"—i. e. the error curve.

The apparatus was shown by Mr. J. A. HARDCASTLE in connection with a discussion of Mr. A. S. EDDINGTON'S[1] investigation confirming KAPTEYN'S theory of two drifts of stars in the "universe." The proper motions of a large number of stars would be expected to turn out as nearly as possible "haphazard," after eliminating the Sun's motion. Mr. EDDINGTON finds that no value can be assigned to the solar motion which will make the outstanding motions of the stars consulted conform to pure chance. The curve of these "residuals," instead of having a single apex, has two. It is as if the box just described had two holes at the top. He has "shown that the outstanding motions can be accounted for only on the hypothesis that the universe—i. e., of course, all the stars consulted—is composed of two groups. In each of his groups the internal motions of the stars composing the group practically completely conform to the required law. So each group can be regarded as an independent whole, while the total visible universe, by the same argument, can no longer be taken as a single entity. Thus we shall have now to speak of the relative motions of the three following items,—viz., (1) the stars composing drift 1 taken as a whole; (2) the stars composing drift 2 taken as a whole; (3) the Sun."

Atmospheric Absorption.—Extensive photometric observations during the year 1906 led M. NORDMANN, of the Paris

[1] *Monthly Notices R. A. S.*, **67**, 34, 1906.

Observatory, and the late Director LŒWY to the remarkable conclusion that, though the absorption of sunlight by the Earth's atmosphere increases, with zenith distance, regularly and rapidly from the red to the violet, the absorption in the case of starlight is, on the contrary, much greater in the red and orange than in the blue and violet. Near the horizon, however, as was to be expected, dust and water vapor scatter the short waves more than the long, so that the absorption of starlight tends to the diurnal type beyond a zenith distance of about 80°.—*Journal B. A. A.*, Vol. XVIII, No. 4.

Field Illumination.—An improved method of illuminating the field in a transit instrument has recently been devised by Sir W. CHRISTIE, Astronomer Royal of England, and Mr. HAROLD CHRISTIE. It had been found that with the axis form of illumination apparatus, in which an adjustable annular reflector was employed, the apparent position of the wires was slightly changed by reversal of the telescope. By attaching the lamp, projecting lens, and reflector to the tube beyond the object-glass (or fastening the reflector to the object-glass itself), the discordance between time observations in the two positions of the telescope has been practically eliminated. In the improved form, the annular mirror is replaced by a central matt-surfaced disk, fixed at 45°, and of sufficient size to avoid certain diffraction effects. The intensity of illumination is regulated by a rheostat. This method of illumination is to be applied to several of the instruments at Greenwich.—*Monthly Notices R. A. S., January, 1908.*

The next meeting of the Astronomical and Astrophysical Society of America will be held at Put-in-Bay Island, Lake Erie, on August 25th and succeeding days.

Mr. RICHARD HINCKLEY ALLEN, of Chatham, N. J., author of "Star Names and Their Meanings," and a life member of the Astronomical Society of the Pacific, died on January 14, 1908, at Northampton, Mass., of pneumonia following an attack of grippe.

M. Baillaud, director of the Toulouse Observatory, has been appointed director of the Paris Observatory, and M. Bourget, adjunct astronomer at the Toulouse Observatory, has been appointed director of the Marseilles Observatory.

The death is announced of Lieutenant-Colonel R. J. L. Ellery, professor of astronomy and late director of the Melbourne Observatory, at the age of eighty years.

The return of Encke's comet was observed by Dr. Wolf at Heidelberg, 1908, January 2. It was afterwards found on a photograph taken at the same observatory, 1907, December 25. The correction to the ephemeris published in *Astronomische Nachrichten*, No. 4222, was $+ 2^m.4, - 24'$.

Mr. H. M. Parkhurst, an amateur astronomer of Brooklyn, N. Y., who did a great deal of work in observing asteroids and variable stars, died January 21st, at the age of eighty-three years.

Sir David Gill, late his Majesty's Astronomer at the Cape, enjoys the unusual honor of having twice received the gold medal of the Royal Astronomical Society. It was first presented to him in 1882 for his work in connection with the determination of the solar parallax, and last evening a second was awarded him in recognition of his contributions to the astronomy of the southern hemisphere.—*Daily Telegraph, London.*

NEW PUBLICATIONS.

Almanaque náutico para el año 1909. Calculado de orden de la Superioridad en el Instituto y Observatorio de Marina de San Fernando. 1907. 4to. xi + 634 pp. Paper.

Annals of Harvard College Observatory. Volume LX. 4to. Nebulæ discovered at the Harvard College Observatory. No VI. 47 pp. Double stars south of — 30°, and of magnitude 6.3 to 7.0. No. VII. 4 pp.

Annuario astronomico del 1908. Publicato dal R. Osservatorio di Torino. 1908. 8vo. 91 pp. Paper.

Anuario del Observatorio Astronómico Nacional de Tacubaya para el año de 1908. 1907. 16mo. 580 pp. Paper.

Astronomisch-geodätische Arbeiten in der Schweiz. Zehnter Band. Zürich. 1907. Folio. ix + 405 pp. Two plates. Paper.

Bailey, Solon I. Peruvian meteorology. Observations made at the Arequipa Station, 1892-1895. Annals of the Astronomical Observatory of Harvard College. Vol XLIX, Part I. Cambridge, Mass. 1907. 4to. 103 pp. Plate. Paper.

Bailey, Solon I. A catalogue of bright clusters and nebulæ. Annals of Harvard College Observatory. Vol. LX, No. VIII. 4to. 30 pp. Five plates. Paper.

Bauschinger, J. Genäherte Oppositions-Ephemeriden von 32 kleinen Planeten für 1908 Januar bis 1908 August. Veröffentlichungen des Königlichen Astronomischen Rechen-Instituts zu Berlin. No. 34. Berlin. 1908. 8vo. 12 pp. Paper.

Bohlin, Karl. Über die Gegenseitige Verteilung der Pole der Doppelsternbahnen der Milchstrasse, des Sonnensystemes sowie des Andromeda-Nebels. Arkiv för Matematik, Astronomi och Fysik, utgifvet af K. Svenska Vetenskapsakademien i Stockholm. Band 3, No. 19. Uppsala and Stockholm. 1907. 8vo. 8 pp. Three plates. Paper.

Börgen, C. Logarithmisch-trigonometrische Tafel auf 11 (bezw. 10) Stellen. Publikation des Astronomischen Gesellschaft, XXII. Leipzig. 1908. Folio. vi + 55 pp. Paper.

BRESTER, A. Essai d'une explication du mécanisme de la periodicité dans le soleil et les étoiles rouges variables. Verhandelingen der Koninklijke Akademie van Wetenschappen te Amsterdam. Deel IX, No. 6. Amsterdam. 1908. 4to. 137 pp. Paper.

Bulletin de l'Observatoire Populaire de Rouen. Année 1907. Rouen. 1908. 8vo. 87 pp. Paper.

Canadian astronomical handbook for 1908. Published by the Royal Astronomical Society of Canada. Toronto. 1907. 16mo. 93 pp. Paper.

COMAS SOLÁ, J. Astronomia y ciencia general; Colección de trabajos cientificos de popularization referentes á la astronomia, á la sismologia, á la historia de las ciencias en el siglo XIX, etc. Barcelona 1907. 4to. 637 pp. Price, 6 pes. 50c.

DONITCH, N. Observations de l'eclipse totale de soleil du 29-30 Août 1905 Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg. St Pétersbourg. 1907. 4to. 28 pp. Four plates. Paper.

EIFFEL, G Atlas météorologique pour l'année 1906. D'après vingt-deux stations Françaises Paris. 1907. Atlas form. Boards.

FRANCOS, SALVADOR GARCIA. Tablas para el cálculo de eclipses de los satélites de *Júpiter* Observatorio de San Fernando. 1907. 4to xi + 23 pp Boards

KING, EDWARD S Standard tests of photographic plates. Annals of Harvard College Observatory. Vol LIX, No. 1. 4to. 32 pp. Plate. Paper.

KRAMER, JULIUS. Untersuchungen und Tafeln zur Theorie der kleinen Planeten von Hekubatypus nebst abgekürzten Bewegungstafeln des Planeten (86) Semele für die Jahre 1900 bis 1951. Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Gottingen. Mathematisch-Physikalische Klasse. Neue Folge. Band V, No. 3. Berlin 1907. 4to. 154 pp Paper.

LOEWY et PUISEUX. Sur l'origine des accidents du sol lunaire. Extrait des Comptes Rendus des séances de l'Académie des Sciences. Tome CXLIV. 4to. 6 pp. Paper.

STEBBINS, JOEL. Photometric observations of double stars. University of Illinois Bulletin, Vol. IV, No 25. Urbana. 1907 8vo. 58 pp Paper. Price, 75 cents.

WHITTAKER, E. T. The theory of optical instruments. Pamphlet. 72 pp Published by the Cambridge University Press. 1907. Price, 2s. 6d. net.

NOTE.—In compiling the above list of New Publications the sizes of books are given in accordance with the table used by the Macmillan Company. As future compilations will be based upon this table, it is inserted here for reference.

A book 1–4 inches	(10 centimeters)	tall is a	48mo.
4–5 inches	(10–12½ cent.)	tall is a	32mo.
5–6 inches	(12½–15 cent.)	tall is a	24mo.
6–7 inches	(15–17½ cent.)	tall is a	16mo.
7–8 inches	(17½–20 cent.)	tall is a	12mo.
8–10 inches	(20–25 cent.)	tall is an	8vo.
10–12 inches	(25–30 cent.)	tall is a	4to.
Larger sizes are			folio.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD AT THE BOHEMIAN CLUB ON MARCH 28, 1908, AT 5:30 P.M.

President CUSHING presided. A quorum was present

The following resolution was adopted:

Resolved That the sum of $196.66, having been advanced by the Life Membership Fund to the Bruce Medal Fund, (see Vol. XI, p. 58, January 28, 1899,) be now refunded by the latter fund to the Life Membership Fund

The Secretary reported that the President had appointed the following committees:—

Auditing: D. S. RICHARDSON (Chairman), J. COSTA, FRANK V CORNISH

Nominating: J. D. GALLOWAY (Chairman), C. D. PERRINE, BEVERLY HODGHEAD, J. K. MOFFITT, OTTO VON GELDERN.

The following named persons were elected to membership —

W. O. OWEN.........U. S. Examiner of Surveys, Imperial, Cal.
ROBERT JONCKHEERE...Roubaix, Nord. France

The following was elected a corresponding institution:—

Remeis Sternwarte, Bamberg, Germany

Adjourned.

Minutes of the Twentieth Annual Meeting of the Astronomical Society of the Pacific, held in [illegible] Hall, [illegible], March 28, 1908, at [illegible]

President [illegible] *called the meeting to order. A quorum was present.*

The Committee on Nominations reported [illegible] *and* [illegible] *were appointed tellers. The polls* [illegible] *the following were duly elected* [illegible] *for the ensuing year:*

For Directors: R. G. Aitken, Charles Burckhalter, W. W. Campbell, [illegible], C. S. Cushing, [illegible], G. E. Hale, [illegible], D. S. Richardson, S. D. Townley.

For Committee on Publication: S. D. Townley, Chairman; [illegible]; J. H. Moore.

REPORT OF THE DONOHOE COMET-MEDAL COMMITTEE FOR THE YEAR 1907

The following comets were discovered during the year 1907:

Comet *a* 1907, an unexpected comet, was discovered by M. Giacobini at Nice, France, on March 9, 1907.

Comet *b* 1907, an unexpected comet, was discovered by J. Grigg, Esq., at Thames, New Zealand, on April 9th, and independently by Mr. J. E. Mellish near Madison, Wisconsin, on April 14th. Announcement of Mr. Grigg's discovery did not reach the astronomers of America and Europe until several weeks had elapsed.

Comet *c* 1907, an unexpected comet, was discovered by M. Giacobini at Nice, France, on June 1st.

Comet *d* 1907, an unexpected comet, was discovered by Mr. Z. Daniel at Princeton, New Jersey, on June 9th.

Comet *e* 1907, an unexpected comet, was discovered by Mr. J. E. Mellish near Madison, Wisconsin, on October 13th.

The Donohoe Comet-Medal of the Astronomical Society of the Pacific has been awarded to the six discoverers mentioned.

The number of Donohoe Comet-Medals awarded to date is sixty-four.

Respectfully submitted,

W. W. Campbell,
C. D. Perrine,
Chas. Burckhalter, } *Committee.*

March 26, 1908.

The Treasurer submitted his Annual Report, as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 28, 1908

GENERAL FUND.

Receipts.

1907. March 31st. Balance			$ 456 25
Received from			
Dues for 1907 and previous years	$244 75		
Dues for 1908 and 1909	399 25		
		$ 644 00	
Sales of *Publications*		37 00	
Life Membership Fund (interest)	$ 67 73		
John Dolbeer Fund (interest)	223 17		
Wm. Alvord Fund (interest)	254 19		
		545 09	
			1,226 09
			$1,682 34

Expenditures

For *Publications*—Printing Nos. 113 to 117	$608 10		
Illustrations	15 50		
		$ 623 60	
Reprints	$ 49 00		
Stationery and printing	111 85		
Postages	58 23		
Salary Secretary	180 00		
Expressages	17 26		
Telegrams	1 25		
Insurance premiums	5 05		
Notary and State fees	11 50		
Rent safe deposit box	5 00		
Bank exchanges	50		
		439 64	
			1,063 24
1908. March 28th. Balance			$ 619 10

Dues outstanding	$600 00
Bills payable—Printing No. 118	$147 45
Sundry printing	25 75
	$173 20

LIFE MEMBERSHIP FUND.

1907 March 31st Balance	$1,727 70
Interest	67 73
	$1,795 43
Less interest transferred to General Fund	67 73
1908 March 28th. Balance	$1,727 70

ALEXANDER MONTGOMERY LIBRARY FUND

1907.	March 31st Balance		$3,501 37
	Interest		177 47
	Contributions by—		
	Mrs. J. H. Devereux	$ 50 00	
	Jas. K. Moffitt	20 00	
	J. D. Galloway	20 00	
	Andrew Greig	10 00	
			100 00
			$3,778 84
	Less Expenditures—		
	Library stamps	$ 6 00	
	Card index	10 00	
	Binding	14 40	
	Allowance to Secretary	40 00	
			70 40
1908.	March 28th. Balance		$3,708 44

BRUCE MEDAL FUND.

1907.	March 31st. Balance		$2,701 65
	Interest		129 51
			$2,921 16
	Less payment to French Mint for one Gold Medal		102 90
1908.	March 28th. Balance		$2,818 26

DONOHOE COMET MEDAL FUND.

1907.	March 31st. Balance		$ 792 66
	Interest		32 44
			$ 825 10
	Less Expenditures—		
	Engraving Medals Nos. 56 and 57, and postage	$ 2 30	
	Payment to French Mint for 100 Medals and cases	77 75	
	Duty, entry, and express	46 70	
			126 75
1908.	March 28th. Balance		$ 698 35

JOHN DOLBEER FUND

1907.	March 31st Balance		$5,000 00
	Interest		223 17
			$5,223 17
	Less interest expended for *Publications* (see General Fund)		223 17
1908.	March 28th Balance		$5,000 00

WILLIAM ALVORD FUND.

1907.	March 31st. Balance		$5,000 00
	Interest		254 19
			$5,254 19
	Less interest expended for *Publications* (see General Fund)		254 19
1908.	March 28th. Balance		$5,000 00

FUNDS.

Balances as follows —

General Fund		
With Donohoe Kelly Banking Company		$ 619 10
Life Membership Fund		
With German Savings and Loan Society	$ 727 70	
South Pacific Coast Railway Co 1st Mortgage 4 per cent guaranteed (by S P Co) $1,000, Gold Bond No. 3406	1,000 00	
(Interest Jan and July, principal due July, 1937)	———	$1,727 70
Alexander Montgomery Library Fund.		
With Security Savings Bank	$ 549 42	
Oakland Transit Consolidated, 1st consolidated Mortgage 5 per cent Gold Bond No 4328	1,040 00	
(Interest Jan and July, principal due July 1932)		
Sunset Telephone and Telegraph Company, consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 641	1,084 02	
(Interest April and Oct ; principal due Oct , 1929.)		
Contra Costa Water Company, 5 per cent, $1 000 Gold Bond No 1665	1,035 00	
(Interest Jan and July, principal due Jan , 1915)	———	3,708 44
Donohoe Comet Medal Fund		
With San Francisco Savings Union		698 35
Bruce Medal Fund.		
With Mutual Savings Bank	$ 828 54	
Bay Counties Power Company, 1st consolidated Mortgage 5 per cent, $1,000 Sinking Fund Gold Bond No 1636	1,012 50	
(Interest March and Sept ; principal due Sept , 1930)		
The Edison Electric Company, Los Angeles, 1st and Refunding Mortgage 5 per cent, $1 000 Gold Bond No 168	977 22	
(Interest March and Sept ; principal due Sept., 1922.)	———	2,818 26
John Dolbeer Fund		
With Union Trust Company	$ 970 28	
South Pacific Coast Railway Company, 1st Mortgage 4 per cent guaranteed (by S P Co), $1,000 Gold Bond No. 3407	1,000 00	
(Interest Jan and July; principal due July, 1937)		
Oakland Transit Consolidated, 1st consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 4329	1,040 00	
(Interest Jan. and July, principal due July, 1932)		
Bay Counties Power Company, 1st consolidated Mortgage 5 per cent $1,000 Sinking Fund Gold Bond No. 1637	1,012 50	
(Interest March and Sept.; principal due Sept., 1930.)		
The Edison Electric Company Los Angeles, 1st and Refunding Mortgage 5 per cent, $1,000 Gold Bond No 169	977 22	
(Interest March and Sept ; principal due Sept , 1922.)	———	5,000 00
William Alvord Fund		
With Humboldt Savings Bank	$ 331 94	
With Savings and Loan Society	428 50	
Sunset Telephone and Telegraph Company, consolidated Mortgage 5 per cent, $1 000 Gold Bond No. 656, and 5 per cent $1 000 Gold Bond No 657	2,168 06	
(Interest April and Oct , principal due Oct., 1929)		
Contra Costa Water Company, 5 per cent $1,000 Gold Bond No 87	1,036 50	
Contra Costa Water Company, 5 per cent $1 000 Gold Bond No. 1666	1,035 00	
(Interest Jan and July; principal due Jan , 1915)	———	5,000 00
		$19,571 85

San Francisco, March 28, 1908.

Examined and found correct

D S. Richardson, } *Auditing*
J. Costa, } *Committee.*

F R Ziel, *Treasurer*

The report was, on motion, accepted and filed

The Auditing Committee submitted the following report:—

SAN FRANCISCO, CAL., March 24, 1908.

TO THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC,
SAN FRANCISCO, CALIFORNIA.

Gentlemen: The undersigned, constituting a majority of the committee appointed to audit the accounts of the Treasurer of this Society for the year just closing, beg to report that they met in the rooms of Treasurer ZIEL on the afternoon of the 21st instant and went over all his accounts with great care. They take pleasure in reporting that they found everything in the best of condition and all funds of the Society properly accounted for. They also visited the vaults of the Mercantile Trust Company, at 464 California Street, and personally inspected the securities of the Society there on deposit, finding all papers in proper order and safely guarded.

As one result of their labors your committee is impressed with the fact that much labor and care is required of the Treasurer in conducting the financial affairs of this Society, and it is their impression that, as a business proposition, a salary should attach to that office, commensurate with the responsibility and importance of the trust.

Very respectfully,

D. S. RICHARDSON, *Chairman*,
J. COSTA,
Auditing Committee.

President CUSHING read an address in awarding the Bruce Medal for 1908 to Director E. C. PICKERING, of Harvard College Observatory.

After his address the President introduced Director W. W. CAMPBELL, of the Lick Observatory, who gave an interesting lecture (illustrated by lantern slides) on "The Crocker Eclipse Expedition from the Lick Observatory, University of California, to Flint Island."

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD MARCH 28, 1908, AT 10 P.M.

The new Board of Directors met and chose Dr. CAMPBELL temporary chairman. A quorum was present.

The election of officers resulted as follows:—

President: CHARLES BURCKHALTER.

First Vice-President: W. W. CAMPBELL.

Second Vice-President: G. E. HALE.

Third Vice-President: F. MORSE.

Secretary: R. T. CRAWFORD.

Secretary (Mt. Hamilton): R. G. AITKEN.

Treasurer: J. D. GALLOWAY.

Library Committee: Messrs. CRAWFORD, TOWNLEY, EINARSON.

Comet-Medal Committee: Messrs. CAMPBELL (ex-officio), PERRINE, TOWNLEY.

The President appointed the following:—

Finance Committee: C. S. CUSHING (Chairman), W. H. CROCKER, R. G. AITKEN.

The President was authorized and instructed to appoint a committee of three to investigate and report to the Directors upon the matter of providing a room in San Francisco for the Society. Messrs C S. CUSHING, J D GALLOWAY, and F. R ZIEL were appointed

The chairman of the Publication Committee was authorized to provide stationery for the use of his committee

The Secretary was instructed to send a letter (to be signed by the President and the Secretary) expressing the appreciation of the Society of the faithful work and long service of the retiring Director and Treasurer, Mr. F. R. ZIEL.

The Secretary was instructed to send a letter (to be signed by the President and Secretary) of thanks to Professor R G. AITKEN, the retiring chairman of the Publication Committee, for his long and excellent service on this committee.

Adjourned.

OFFICERS OF THE SOCIETY

Mr Charles Burckhalter. .... *President*
Mr W W Campbell.......................... *First Vice President*
Mr G. E Hale .... *Second Vice-President*
Mr F Morse. .... *Third Vice-President*
Mr R T Crawford (Students' Observatory, Berkeley).............. *Secretary*
Mr R G Aitken (Mount Hamilton, Cal).......................... *Secretary*
Mr J D. Galloway.......................... *Treasurer*

For Directors—Aitken Burckhalter Campbell Crawford, Crocker Cushing Galloway Hale, Morse, Richardson, Townley.

Finance Committee—Messrs Cushing Crocker, Aitken.

Committee on Publication—Messrs Townley, Maddrill, Moore.

Library Committee—Messrs. Crawford, Townley, Einarson

Comet Medal Committee—Messrs. Campbell (ex officio), Perrine Townley

NOTICE

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only Subsequent annual payments are due on January 1st of each succeeding calendar year This rule is necessary in order to make our bookkeeping as simple as possible Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied Members are requested to preserve the copies of the *Publications* of the Society as sent to them Once each year a title page and contents of the preceding numbers will also be sent to the members who can then bind the numbers together into a volume Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S P., Students' Observatory, Berkeley, Cal, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience In a general way, those papers are printed first which are earliest accepted for publication Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

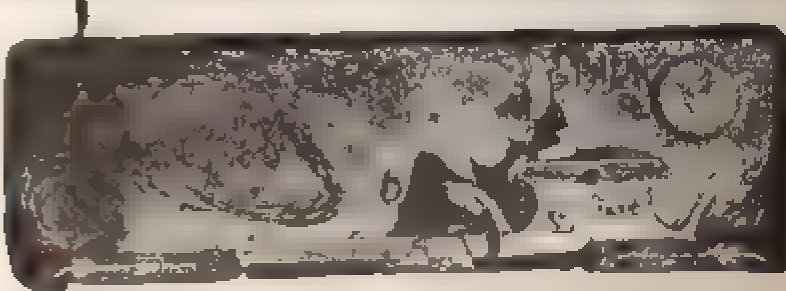
The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows a block of letter paper 40 cents, of note paper, 25 cents a package of envelopes, 25 cents These prices include postage, and should be remitted by money order or in U. S postage stamps. The sendings are at the risk of the member.

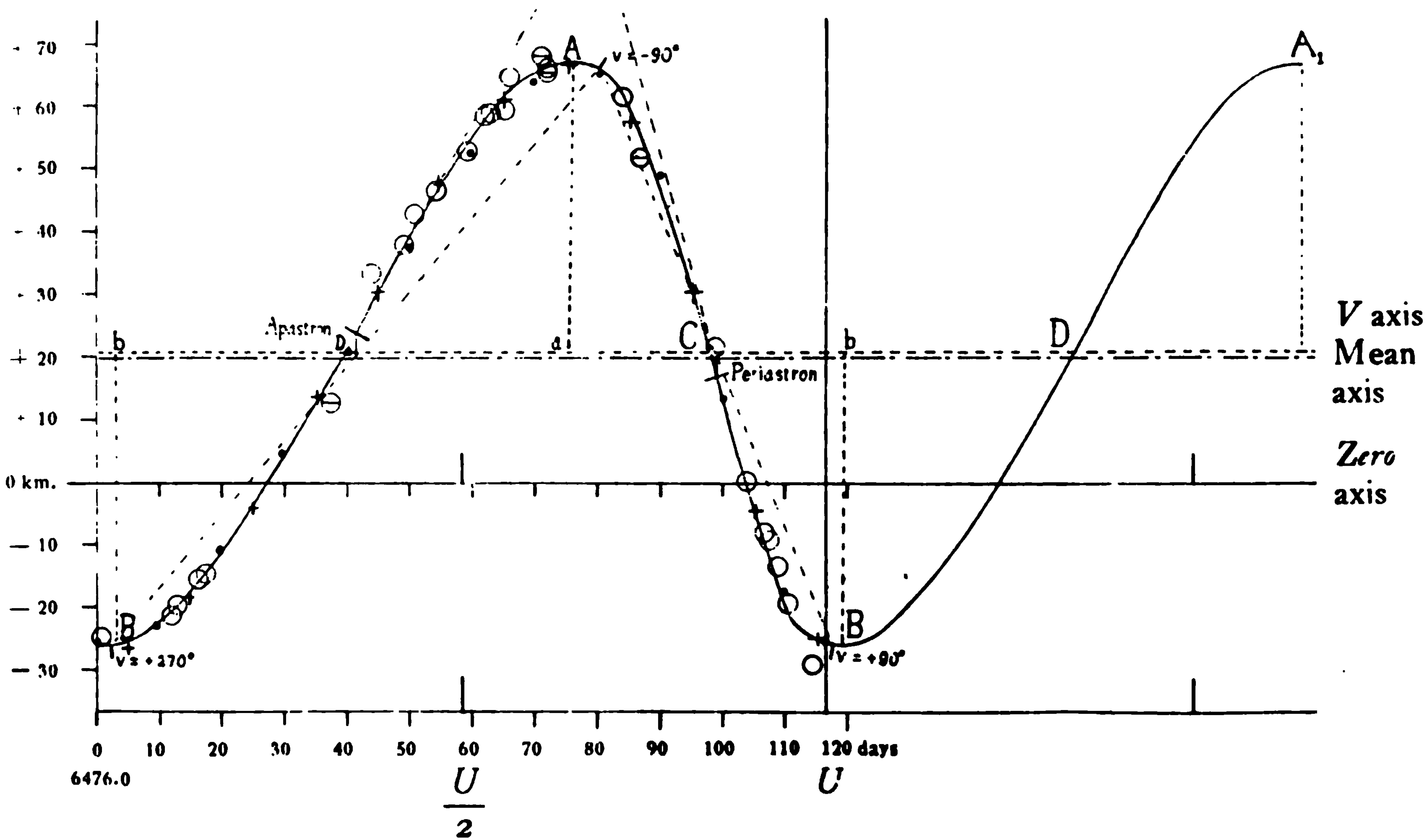
Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI MONTHLY.

(February, April June, August, October, December.)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco, California Subscription price, $5 00 per year.

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Apastron
Periastron
v = -90°
v = +270°
v = +90°
V axis
Mean axis
Zero axis

FIGURE 2.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XX. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1908. No. 120.

METHODS OF DETERMINING THE ORBITS OF SPECTROSCOPIC BINARIES.

By HEBER D. CURTIS.

With the constantly increasing number of discoveries in this field of spectrographic research, the subject of spectroscopic binaries as a whole has become an exceedingly important one in its bearing on theories of stellar evolution. Thirty, or even twenty, years ago it would have seemed beyond the bounds of reasonable conjecture that at least one in every seven or eight of the brighter stars should prove to be a double star whose components are impossible of separation in any telescope existing or whose construction is conceivable. It is unnecessary to speak of the importance of the results already secured in relation to theories of cosmogony. As one conclusion only, we are led to think that our Sun, with its retinue of small planets, may possibly be a rather exceptional case in stellar development, the more common case being the fission of a star into two or more masses of the same order of magnitude.

The number of these systems is increasing to-day at a rapid rate. Including those whose binary character is under investigation, but not sufficiently substantiated for publication, the number is now about two hundred; and, with the carrying of spectrographic surveys down to fainter stars, we may need four figures to express the total in the not distant future.

It seems improbable at present that the labor of "keeping track" of all these systems will ever present the difficulties which make the asteroid group rather an embarrassing source of astronomical wealth, though we cannot, of course, premise

just what interesting developments may be gained as to the inner mechanism of these systems from a comparison of their orbits of to-day with their forms one hundred years hence. It is not too much to suppose that the student of celestial mechanics may then find in this field "laboratory demonstrations" of the problem of three or more bodies, while possible changes in the periods and eccentricities could be expected to give valuable results to the worker in theories of tidal evolution of planets and satellites.

In the sphere of double stars we now have an unbroken continuum, from the spectroscopic binary of a few hours' rotation period to the visual double star with a period so long that centuries will be necessary for an accurate determination of the orbital elements. Some five or six stars are known to be both spectroscopically and telescopically double, and these serve to bind together the two fields. Visual double-star observers to-day are agreed that the greatest present progress in their branch of this wide field is to be derived from the systematic measurement of the systems of shorter period, from five to fifty years. It is in just this point of shortness of period that the spectroscopic field has the advantage in the point of evolutional developments. To take an extreme case: In the interesting quadruple system of *Castor* the published spectrographic observations of a_1, the fainter component, extend over eleven years and cover no less than fourteen hundred complete revolutions, while for the visual system the telescopic measures extending over one hundred years cover so short an arc that the visual elements must remain uncertain for a long time to come.

The actual determination of the elements of a spectroscopic binary is comparatively easy. From twenty to thirty plates, if well distributed over the period of revolution, are ample, in most cases, to secure satisfactory values of the elements of the system. The securing of these plates is the time-consuming factor in the problem, however, which perhaps explains why, for about seventy-five per cent of known spectroscopic binaries, we are still without accruate elements. While a skilful observer of visual double stars can make and reduce a complete single set of measures in fifteen to twenty minutes, including in this the time taken in passing from one star of

his programme to another, from half an hour to two or more hours is required for the exposure time alone of a single spectrographic plate. Developing, measuring, and reducing, unless but few lines are available in the spectrum, will take several hours more. From a consideration of these points it may easily be seen that the determination of the orbits of three or four hundred spectroscopic binaries would require in the neighborhood of ten thousand plates,—easily twenty years' work for a single observatory, however favorably located as to climatic conditions.

Doubtless for some years to come the individual observatories possessing powerful spectrographs for radial-velocity determinations will endeavor to compute the elements of the binaries discovered by themselves. But it seems probable that the time must come when there will be systematic co-operation, to some extent at least, in order to secure greater rapidity in utilizing the data at present available and to be accumulated, and to prevent unnecessary duplication of work.[1]

As no recent treatment of the various methods for the determination of the elements of a spectroscopic binary exists in English, it is the purpose of this paper merely to collect in accessible form some of the more approved methods of solving the problem, with a few hints as to the processes involved, but without pretending to advance any new matter on the subject.

The more important papers on the subject may be referred to as follows:—

RAMBAUT, *M. N.*, Vol. LI, pp. 316 ff.
WILSING, *A. N.*, **134**, 90, 1893.
RUSSELL, *Aph. J.*, **15**, 252, 1902.
LEHMANN-FILHÉS, *A. N.*, **136**, 17, 1894.
SCHWARZSCHILD, *A. N.*, **152**, 65, 1900.
BAUSCHINGER, "Bahnbestimmung der Himmelskörper," pp. 647 ff.
ZURHELLEN, *A. N.*, **173**, 353, 1907.
ZURHELLEN, *A. N.*, **175**, 245, 1907.

[1] For several years the Lick Observatory has been keeping records of work in this field,—a task necessitated by the need for systematizing its own efforts,—and as a result it was found wise to collect the material available in a "First Catalogue of Spectroscopic Binaries" (CAMPBELL and CURTIS, *Lick Observatory Bulletin*, No. 79, 1905). From time to time, as the need arises, successive catalogues will be issued.—W. W. C.

Of these methods, that of RAMBAUT is considerably longer and more involved than later methods and need not be considered here. WILSING'S method, as originally published, was suitable only for orbits of small eccentricity, but Dr. RUSSELL has extended it so as to make it applicable to larger eccentricities as well. The method of WILSING and RUSSELL is purely analytical, and in time consumed is considerably longer than the geometrical methods of LEHMANN-FILHÉS, SCHWARZSCHILD, and ZURHELLEN. It consists in finding a Fourier's series for the velocity in terms of the elements. It should be very useful in special cases, particularly when the period is so nearly a year that one part of the velocity-curve is not represented by any observations. Another special application suggested by RUSSELL is its use as a method of trigonometrical analysis in disentangling the superposed elements of a triple or other multiple system. These longer methods will not be further treated here.

The spectroscopic plates give us a series of irregularly distributed radial velocities of the star, and the first problem is the determination of the approximate period, which rarely offers any difficulty. This should be done as early as possible in order to distribute the plates evenly over the revolution period and to fill up any gaps which may have been left by earlier plates. Different series of plates will differ so widely in their arrangement that the determination of each particular period is a separate problem. The observation times are most conveniently expressed in Julian days and decimals of a day. By choosing an epoch, preferably a maximum or minimum near the beginning of the series, a probable approximate value of the period is easily secured by the use of co-ordinate paper. When a number of maxima and minima are well defined, wide divergencies in other regions of the curve may generally be removed by trying a new period, some sub-multiple of the first period assumed. Then by subtracting multiples of the adopted period from the observation dates all the observations are reduced to a curve covering one revolution beginning at the assumed epoch, with the abscissæ as times from the adopted date of maximum or minimum, and the observed velocities as the ordinates. After the preliminary curve is drawn, by noting the deviations from the curve at points near the mean of the

maximum and minimum velocities, where a change in the periodic time will have the greatest effect, advisable changes in the preliminary assumed period are readily found by dividing the deviations of such critical observations, expressed in time, by the number of revolutions elapsed. A second curve may then be drawn, whose periodic time will generally be very close to the true one. For all this preliminary work a calculating machine is a great time-saver, though a simple table of multiples of the period will be almost as rapid. For stars whose periods are almost exact multiples of a day, and short, it may be necessary to wait some time before observations can be secured over all the velocity curve. The same may be true for orbits nearly a year in length, unless the analytical method of WILSING and RUSSELL be used in these cases.

After the period has been determined as carefully as possible the "most probable curve" is drawn, by estimation, through the observation points as plotted; and it is well to prolong this curve through a revolution and a half, in order to be able to use the ingenious methods of superposition devised by SCHWARZSCHILD and ZURHELLEN.

The errors in drawing this curve have considerable effect on the accuracy of the determination of the elements. The most probable curve which even a practiced hand may draw is not likely to be a perfect representation of the elliptic motion which caused it, as it is natural to bend the curve slightly in or out at various points to satisfy the more or less exact observations. This difficulty is fundamental in all methods of treatment, and for it there seems to be no remedy other than by testing rapidly the first orbit found by a trial ephemeris and making the needful small changes in the elements, to which reference will be made later.[1]

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[1] Though ZURHELLEN mentions this unavoidable curve-error earlier in his valuable paper, it appears that he has not duly taken it into account, in the comparisons which he makes at the close of his paper, of the values of ω and the eccentricity secured by his methods and those obtained by other investigators using other methods. His values, it is true, are quite close to the values secured, in some cases, by a rigorous least-square solution, but his values have evidently been derived from the *final* curves as published. These, of course, are accurately drawn from ephemerides and are very approximately true representations of the line of sight component of the velocity in an elliptic orbit. Had he applied his methods to the original preliminary curves used by the investigators with whose work he makes comparisons, he would doubtless have found values as far removed from the final ones as are the preliminary values secured by the method of LEHMANN-

Figure 2 gives a preliminary velocity-curve as actually drawn for the determination of the orbit of the spectroscopic binary *κ Velorum*. The observations used were as follows:—

Julian Day, G. M. T.	Vel.	Julian Day, G. M. T.	Vel.
2416546.739	+ 68.5^{km}	2417686.591	+ 33.8^{km}
60.703	+ 12.9	91.572	+ 38.2
97.651	+ 65.7	92.545	+ 43.2
6912.601	+ 53.3	96.480	+ 46.7
7587.844	+ 58.6	7701.494	+ 52.7
88.788	+ 57.9	41.466	+ 22.1
90.829	+ 58.5	46.463	+ 0.3
91.824	+ 64.8	49.470	— 7.6
97.788	+ 65.8	50.479	— 8.8
7609.790	+ 62.0	51.463	— 13.3
54.534	— 21.0	53.457	— 19.2
55.556	— 19.2	58.451	— 29.0
58.570	— 15.2	59.460	— 24.6
59.545	— 14.5		

The small circles representing the first four observations, which are important in determining the period, owing to their distance in time from the later ones, are barred in the diagram. The period, *U*, was assumed to be 116.65 days, and the beginning of the curve is at Julian day 2416476.0. This is not exactly at a minimum, as may be seen from the diagram.

The conditions of the problem are illustrated in Figure 1. The XY-plane is taken as the plane tangent to the celestial sphere at the center of motion, the Z-axis being the line of sight in which the velocities are measured, and perpendicular to the XY-plane. The orientation of the X and Y axes in space remains unknown. It will be seen at once that the

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FILHÉS. Taking the *final* curve of a_2 *Geminorum* as published, and using a planimeter, I find by the method of LEHMANN-FILHÉS the following values:—

Lehmann-Filhés.	Final Elements.
$e = 0.501$	$e = 0.503$
$\omega = 265°.36$	$\omega = 265°.35$

Using the same procedure for the curve of *β Aurigæ* as published with ZURHELLEN'S paper, I derive $e = 0.144$, in close agreement with the value from his method No. 8, ($e = 0.142$); for both his method No. 8 and that of LEHMANN-FILHÉS are equally sensitive to an erroneous placing of the maximum, which obtains in this curve. Shifting the maximum back a distance 0.01 *U*, as suggested in the paper quoted, I find $e = 0.11$ (ZURHELLEN, mean of eight methods, $e = 0.106$).

problem is somewhat different from that in which the orbit of a visual double is determined. In that case the data are the observed distances and position-angles at certain epochs, which, when plotted, give us a projected ellipse, while the spectrographic data are simply the times and the corresponding velocities directly toward or directly away from the observer (+ when the distance from the Sun is increasing). The true velocities or the direction of motion in the orbital ellipse, and the size and the position in space of the actual orbit, must of course always remain unknown, except in the comparatively rare cases where visual and spectrographic observations can be combined. It is manifest, moreover, that if the orbit-plane were coincident with the XY-plane, such a binary could not be detected spectroscopically, as there would then exist no component of the velocity in the line of sight.

The following customary notation will be used:—

U = Period,
μ = mean daily motion,
i = inclination of orbit to XY-plane (not determinable),[1]
Ω = ascending node on XY-plane (not determinable),
a = semi-major axis of true ellipse " "
p = semi-parameter of true ellipse " "
ω = angular distance of periastron from ascending node,
u = argument of the latitude, $u = v + \omega$,
r = radius vector,
t = the time,
T = the time of periastron passage,
v, M, E = true, mean, and eccentric anomalies respectively,
e = eccentricity, $= \sin \phi$, where ϕ is the eccentric angle.
V = the velocity of the center of mass of the system as a whole (ZURHELLEN'S γ).
f = constant of attraction.[2]

---

[1] While a and i are separately indeterminable, it will be seen later that we can find the value of $a \sin i$, from which we may assign a minimum for a.

[2] In the great majority of spectroscopic binaries the spectrum of one component only is visible. This does not necessarily mean that the companion is dark, but merely that it is considerably fainter. In this case the motion of the bright star

By reference to Fig. 1 it will be seen that the distance from a point S in the orbit to the XY-plane will be

$$z = r \sin i \sin u.$$

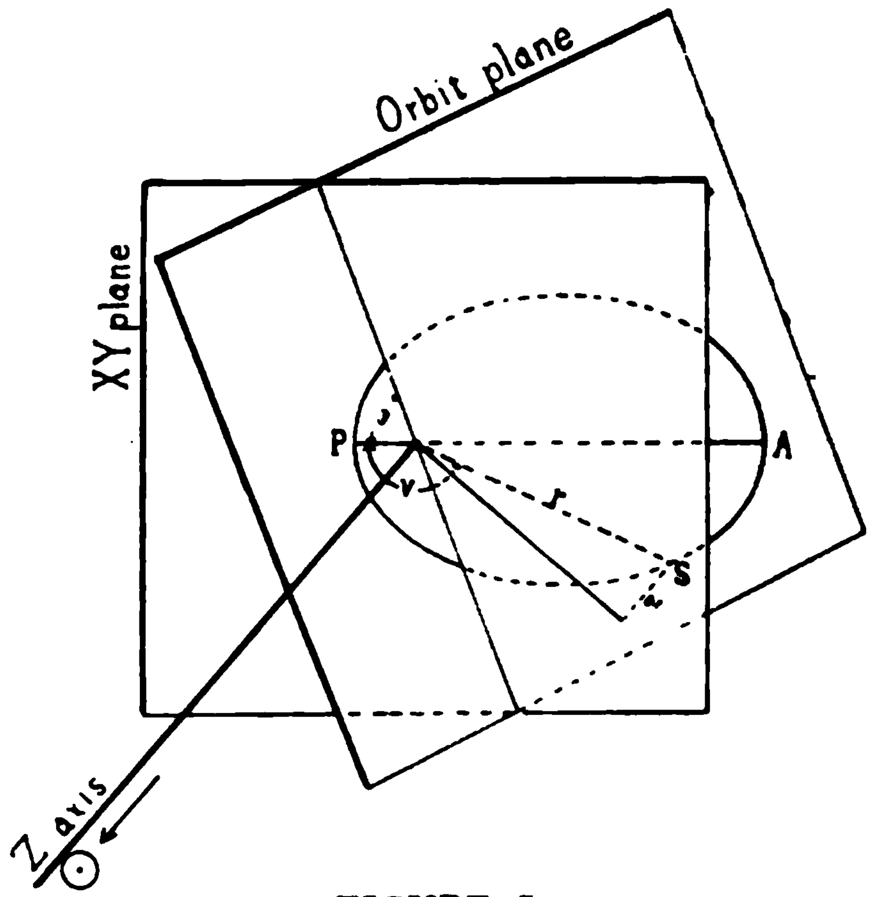

FIGURE 1.

The spectrograph gives us, however, not the distances from the XY-plane, but the *velocities* of the star's approach or recession from this plane, generally expressed in kilometers per second, and evidently equal to dz/dt.

Hence, differentiating,

$$\frac{dz}{dt} = \sin i \sin u \frac{dr}{dt} + r \sin i \cos u \frac{du}{dt}.$$

From the known laws of elliptic motion we may substitute the values

$$\frac{dr}{dt} = \frac{f}{\sqrt{p}} e \sin (u - \omega),$$

$$r\frac{du}{dt} = \frac{f\sqrt{p}}{r} = \frac{f}{\sqrt{p}} [1 + e \cos (u - \omega)].$$

These substitutions give for the fundamental equation

$$\frac{dz}{dt} = \frac{f}{\sqrt{p}} \sin i (\cos u + e \cos \omega). \qquad (1)$$

---

is determined with reference to the center of gravity of the system and the constant of attraction has the value

$$\frac{k m^{\frac{3}{2}}}{m + m'},$$

where k is the Gaussian constant. If both components are visible in the spectrum and the motion of one mass with reference to the other is determined, $f = k \sqrt{m + m'}$.

Now the curve of the observed velocities will have the general appearance of a distorted sine-curve with a maximum and a minimum at the points A and B in Fig. 2, but it is evident that the curve as a whole is shifted a distance above or below the zero axis by an amount equal to the velocity of approach or recession of the binary system as a whole, and before the observed values can be made purely periodic the velocity of the center of mass of the system, which is a constant quantity for a single system, must be eliminated from the observation values. Methods of finding the position of the line representing the velocity of the center of mass of the system will be noted later, but for a study of some of the properties of the curve we will suppose for the present that this velocity of the system as a whole is known, and is represented by the dotted line in Fig. 2. This will be called the V-axis.

It is evident from equation (1) that for a maximum velocity $\cos u = 1$, and for a minimum $\cos u = -1$; i. e., at the point A of the curve, $u = 0$; and at B, $u = 180°$; or, A and B are the points corresponding to the star's passage through the ascending and descending nodes of its orbit, respectively. Taking, then, A and B as the magnitudes of the curve ordinates at the points of maximum and minimum reckoned from the V-axis, B being taken as a positive quantity, we have

$$\mathrm{A} = \frac{f}{\sqrt{p}} \sin i\,(1 + e \cos \omega),$$

$$\mathrm{B} = \frac{f}{\sqrt{p}} \sin i\,(1 - e \cos \omega).$$

From these equations it is clear that the term $\frac{f}{\sqrt{p}} \sin i$ is the half amplitude of the curve in Fig. 2. This will be denoted by K,—i. e.

$$\frac{f}{\sqrt{p}} \sin i = K = \frac{\mathrm{A} + \mathrm{B}}{2},$$

$$\frac{f}{\sqrt{p}} \sin i\, e \cos \omega = \frac{\mathrm{A} - \mathrm{B}}{2},$$

$$e \cos \omega = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A} + \mathrm{B}}.$$

The expression for the velocity measured from the zero-axis may then be written, by placing $V' = V + \frac{A - B}{2}$,

$$\frac{dz}{dt} = V' + K \cos u. \qquad (2)$$

Instead of using the ordinates A and B measured from the V-axis to find K, we may of course take the corresponding values from the zero-axis, replacing $\frac{A + B}{2}$ by $\frac{M_1 - M_2}{2}$, where M_1 and M_2 are the ordinates of maximum and minimum respectively, measured from the zero-axis.

Given the curve and the above fundamental equations, quite a variety of methods may be used to find the elements, all requiring about the same amount of time, providing that a planimeter is available when using the method of LEHMANN-FILHÉS. If the computer is not provided with one of these convenient instruments, the methods of SCHWARZSCHILD and ZURHELLEN will be more expeditious. Accordingly these methods will be treated first.

SCHWARZSCHILD'S METHOD OF FINDING THE PERIASTRON TIME, T.

Given M_1 and M_2, the observed velocities of maximum and minimum as measured from the zero axis, draw the line whose ordinate is $\frac{M_1 + M_2}{2}$. In Fig. 2, $M_1 = + 66.4$, $M_2 = - 26.8$, therefore $(M_1 + M_2)/2 = + 19.8$. This line will be called the *mean* axis, and is represented in Fig. 2 by the dot-and-dash line. Mark on this axis the points $U/2$ and $3U/2$; then lay a piece of semi-transparent paper over the curve and copy on this the curve with the mean axis, marking also the points 0, $U/2$, U, and $3U/2$. Shifting this copy bodily along the mean axis for a distance $U/2$, rotate the copy 180° about the mean axis —i. e. turn the copy face downward on the original curve, keeping the mean axis in coincidence, and bringing the point 0 or U of the copy over the point $U/2$ of the curve. The curves will then cut one another in general in four points, of which two will be the points of periastron and apastron. The proper two points will be found without difficulty, for peri- and

apastron must be separated in time by one half a revolution, and must, moreover, lie on different branches of the velocity-curve. To determine which is periastron we have the criteria: (1) at periastron the velocity-curve is steeper with regard to the axis than at apastron; (2) the curve is for a shorter time on that side of the mean axis on which the point of periastron lies. By following this procedure we find in Fig. 2 that periastron lies at the point + 98.8 days from the epoch, giving for the dates of periastron J. D. 2416458.15, 6574.80, etc.

This ingenious method is exceedingly good, though the writer prefers the method of LEHMANN-FILHÉS when the eccentricity is small. In these cases ω and T are quite indeterminate, and small errors in drawing the velocity-curve will be very troublesome.

METHOD OF DETERMINING THE ANGLE OF PERIASTRON, ω.

It may easily be verified that $V' = V + K\,e \cos \omega$ represents the position of the mean axis, and accordingly that the ordinate of any curve point, referred to the mean axis, may be secured from

$$\zeta = \frac{dz}{dt} - V' = K \cos u.$$

Now at periastron $v = 0$ and hence $u = \omega$; therefore, if we call the ordinate of periastron from the mean axis ζ_p, we have

$$\cos \omega = \frac{\zeta_p}{K}.$$

Or, better, we may use the ordinates of both peri- and apastron,

$$\cos \omega = \frac{\zeta_p - \zeta_a}{2K}.$$

Both of these methods are at their best when ω is near 90°. From Fig. 2 we take $\zeta_p = -3.2$; $K = 46.6$; hence $\omega = 93°.9$. Or, $\zeta_p = -3.2$; $\zeta_a = +3.9$; $\zeta_p - \zeta_a = -7.1$; and $\omega = 94°.4$. An entirely analogous equation may be used in case the position of the V-axis is known. This is generally most accurately determined by a planimeter and the method of LEHMANN-FILHÉS, to be given later, but may also be found from the mean axis by the requirement that the V-axis must

lie at a distance equal to $-Ke\cos\omega$ above the mean axis. Calling the ordinates measured from the V-axis, z, we may find

$$\cos\omega = \frac{z_p - z_a}{2K}.$$

Another method of finding ω, due in its simplified form to ZURHELLEN, is best when ω is small. It consists in finding the points on the velocity-curve where the true anomaly is equal to $\pm 90°$. From the fundamental equation,

$$\zeta_1 = \frac{dz_1}{dt} - V = K(\sin\omega + e\cos\omega),\ \text{for } v = -90°,$$

and

$$\zeta_2 = \frac{dz_2}{dt} - V = K(-\sin\omega + e\cos\omega),\ \text{for } v = +90°;$$

or,
$$\zeta_1 = +K\sin\omega,$$
$$\zeta_2 = -K\sin\omega.$$

Moreover, at the points $v = \pm 90°$,

$$E_1 = -E_2,$$
$$M_1 = -M_2,$$
$$t_1 - T = -(t_2 - T):$$

hence these points lie symmetrically in ζ to the mean axis, and in time to the periastron. They may accordingly be determined by rotating the curve copy 180° about the point of intersection of the ordinate of periastron with the mean axis, when the two intersections of the copy with the original curve will give the points sought. The point $v = +270°$ may be found in like manner. As a check on the location of these points draw the lines connecting the points $v = +270°$ and $v = -90°$, also that from $v = -90°$ to $v = +90°$. These lines should cut the mean axis at its intersections with the ordinates of apastron and periastron, respectively. Calling the ordinates measured from the mean axis ζ_1 for the point $v = -90°$, and ζ_2 for the point $v = +90°$, then

$$\sin\omega = \frac{\zeta_1 - \zeta_2}{2K},\ \text{or}\ \tan\omega = \frac{\zeta_1 - \zeta_2}{\zeta_p - \zeta_a}.$$

This method is at its least advantage in the example given in Fig. 2, for here ω is close to 90°. At $v = -90°$ in the figure

we find its ordinate from the mean axis to be $+46.1$, while for $v = +90°$ we find -45.4.

Hence $\sin \omega = 91.5/93.2$, and $\omega = 101°.0$.

Other interesting properties of the velocity-curve and methods for finding the periastron-angle and eccentricity are derived by ZURHELLEN. For instance, by rotating the curve copy about the intersection of the periastron ordinate with the V-axis instead of with the mean axis, we may find the curve points where the eccentric anomalies are equal to $\pm 90°$. But these additional methods will not in general offer any advantages over those already given.

METHODS OF DETERMINING THE ECCENTRICITY.

1. Perhaps the best is ZURHELLEN'S method of drawing the tangents to the curve at the points of periastron and apastron. These can be drawn with considerable accuracy, except when the periastron falls near a maximum or minimum of the curve, for in this case slight changes in the position of periastron will cause considerable changes in the inclinations of the tangent-lines. The expression for the tangent will be

$$\frac{d\zeta}{dt} = \frac{2\pi}{U} \cdot \frac{d\zeta}{dM} = \frac{2\pi}{U} \frac{1}{1 - e\cos E} \cdot \frac{d\zeta}{dE}.$$

From $u = v + \omega$, and by introducing the known values

$$\cos v = \frac{\cos E - \sin \phi}{1 - e \cos E}, \quad \sin v = \frac{\cos \phi \sin E}{1 - e \cos E},$$

the original velocity equation will take the form

$$\zeta = \frac{dz}{dt} = K \cos \phi . \frac{\cos \phi \cos \omega \cos E - \sin \omega \sin E}{1 - e \cos E};$$

whence

$$\frac{d\zeta}{dt} = \frac{2\pi}{U} K \cos \phi . \frac{-\cos \phi \cos \omega \sin E - \sin \omega \cos E + e \sin \omega}{(1 - e \cos E)^3}.$$

At periastron $E = 0$, and at apastron $E = \pi$; whence

$$\frac{d\zeta}{dt_p} = \frac{-2\pi K \cos \phi \sin \omega}{U(1 - e)^2},$$

$$\frac{d\zeta}{dt_a} = \frac{+2\pi K \cos \phi \sin \omega}{U(1 + e)^2}.$$

From these values

$$\frac{\tan_p}{\tan_a} = \left(\frac{1+e}{1-e}\right)^2 = -q^2,$$

$$\text{or} \quad e = +\frac{q-1}{q+1}$$

In Fig. 2 the value of the tangent at periastron is 104°.8, while at apastron it is 60°.9; whence $q = 1.45$ and $e = 0.18$.

2. Draw the V-axis and determine the ordinates from this axis of the maximum and the minimum, and also of peri- and apastron. Using z for these ordinates,

$$e = \frac{z_{\text{max}} + z_{\text{min}}}{z_p - z_a}.$$

3. The following method is that of SCHWARZSCHILD as simplified by ZURHELLEN. It is best when ω is small, and to be applicable for eccentricities over 0.2 implies the use of SCHWARZSCHILD'S table, of which the necessary portion is given below. It depends upon the difference in time of the ordinates of the points $v = \mp 90°$, before determined.

Since $\tan \frac{1}{2} E = \tan \frac{1}{2} v \tan (45° - \frac{1}{2} \phi)$, for $v = \mp 90°$, we have $\tan \frac{1}{2} v = \mp 1$, and therefore $E_1 = -(90° - \phi)$ and $E_2 = +(90° - \phi)$. Similarly,

$$M_1 = -(90° - \phi) + \frac{\sin \phi \sin (90° - \phi)}{\sin 1''},$$

$$M_2 = +(90° - \phi) - \frac{\sin \phi \sin (90° - \phi)}{\sin 1''},$$

$$M_2 - M_1 = \frac{360°}{U}(t_2 - t_1) = 180° - 2\phi - \frac{\sin (180° - 2\phi)}{\sin 1''},$$

$t_2 - t_1$ may be read off directly from the diagram, and $90° - \phi$ can then be taken directly from SCHWARZSCHILD'S table. For small values of e ($\phi < 12°$, $e < 0.2$) the table may be replaced by the shorter formula,

$$\phi = 90° \left(\frac{1}{2} - \frac{t_2 - t_1}{U}\right).$$

From Fig. 2 we have $t_1 = 80.0$ days, $t_2 = 117.8$ days, hence $\frac{t_2 - t_1}{U} = 0.324$; whence from the table, $90° - \phi = 73°.7$ and $e = 0.28$. Using the shorter formula, $e = 0.27$. The di-

vergence from the other values which have been secured is because ω is so near to 90°, the most unfavorable case for this method.

SCHWARZSCHILD'S TABLE FOR THE EQUATION

$$2\eta - \sin 2\eta = 2\pi \frac{t_2 - t_1}{U}.$$

η	$\frac{t_2 - t_1}{U}$	η	$\frac{t_2 - t_1}{U}$	η	$\frac{t_2 - t_1}{U}$
0°	0.0000	30°	0.0290	60°	0.1956
1	0.0000	31	0.0318	61	0.2040
2	0.0000	32	0.0348	62	0.2125
3	0.0000	33	0.0380	63	0.2213
4	0.0001	34	0.0414	64	0.2303
5	0.0001	35	0.0450	65	0.2393
6	0.0002	36	0.0488	66	0.2485
7	0.0004	37	0.0527	67	0.2578
8	0.0006	38	0.0568	68	0.2673
9	0.0008	39	0.0611	69	0.2769
10	0.0011	40	0.0656	70	0.2867
11	0.0015	41	0.0703	71	0.2966
12	0.0020	42	0.0751	72	0.3065
13	0.0025	43	0.0802	73	0.3166
14	0.0031	44	0.0855	74	0.3268
15	0.0038	45	0.0910	75	0.3371
16	0.0046	46	0.0967	76	0.3475
17	0.0055	47	0.1025	77	0.3581
18	0.0065	48	0.1085	78	0.3687
19	0.0077	49	0.1147	79	0.3793
20	0.0089	50	0.1212	80	0.3900
21	0.0103	51	0.1278	81	0.4008
22	0.0117	52	0.1346	82	0.4117
23	0.0133	53	0.1416	83	0.4226
24	0.0151	54	0.1488	84	0.4335
25	0.0170	55	0.1561	85	0.4446
26	0.0191	56	0.1636	86	0.4557
27	0.0213	57	0.1713	87	0.4667
28	0.0237	58	0.1792	88	0.4778
29	0.0262	59	0.1873	89	0.4889
30	0.0290	60	0.1956	90	0.5000

METHOD OF LEHMANN-FILHÉS.

It has not seemed advisable to segregate the separate steps in this method for inclusion with the other methods given before. The method of LEHMANN-FILHÉS will be found very generally useful, and little, if any, longer than other methods, providing a planimeter is used.

Given the observations and the velocity-curve, the first step is the fixing of the position of the velocity of the center of gravity of the system,—the so-called V-axis. This is found by the requirement that the integral of dz/dt,—that is, the area of the velocity-curve,—must be equal for the portions of the curve above the V-axis and below it. By far the easiest method of performing this integration is to use a planimeter. A line is first drawn by estimation as nearly in the correct position to fulfil the requirement of equal areas as can be judged by the eye. Placing the planimeter pointer at the intersection of this line and the curve, trace out the curve lying on one side of the line in, say, a clockwise direction, and, on reaching the starting point, traverse the portion of the curve on the other side of the line, in the counter-clockwise direction. The readings of the planimeter will then give directly the difference in the two areas, and the position of the V-axis may be shifted slightly to correct the difference. A second double circuit by the planimeter will generally be all that is necessary to secure an accurate value of the position of the V-axis, not depending simply upon the magnitude of maximum and minimum as in the previous methods, but supported by the entire curve. The increased accuracy is of little importance, however, as it will be found best to correct whatever value of V may be adopted by the residuals from the final ephemeris. If a planimeter is not available, doubtless the best method to equalize the areas above and below the curve will be to draw the curve on cross-section paper and make a count of the small squares, as suggested by RAMBAUT. The position may also be found by an approximate mechanical integration, as advised by LEHMANN-FILHÉS, but in such a case the shorter methods explained above for finding the elements would generally be given the preference.

Given the position of the V-axis, the ordinates should next be drawn at the points of maximum and minimum velocity

(Aa, Bb in Fig. 2). It is at this point that this method is weakest and most subject to error, for slight errors in the fixing of the positions of these ordinates may easily arise. It is best to check the positions of these ordinates by the requirement that the curve portion AaC must be equal in area to CbB, while DaA = BbD.

Considering V as eliminated from the velocities, at the curve points C and D, we have $dz/dt = 0$; hence, from the fundamental velocity equation,

$$\cos u = -e \cos \omega = -\frac{A-B}{A+B}.$$

The argument of the latitude, u_1, corresponding to the point C, lies on the way from the ascending to the descending node, hence sine u_1 is positive. Then,

$$\sin u_1 = \frac{2\sqrt{AB}}{A+B},$$

$$\cos u_1 = -\frac{A-B}{A+B} = -e \cos \omega;$$

while for u_2 at the point D

$$\sin u_2 = -\frac{2\sqrt{AB}}{A+B} = -\sin u_1,$$

$$\cos u_2 = -\frac{A-B}{A+B} = \cos u_1.$$

Denoting the area of AaC by Z_1, and bBD by Z_2 (it will be seen that these areas represent the distances of the star from the XY-plane when at the points of its orbit corresponding to the arguments of the latitude u_1 and u_2) and the radii vectors by r_1 and r_2, we have

$$Z_1 = r_1 \sin i \sin u_1,$$

$$Z_2 = r_2 \sin i \sin u_2 = -r_2 \sin i \sin u_1,$$

$$\frac{r_1}{r_2} = -\frac{Z_1}{Z_2}.$$

Then, since

$$r_1 = \frac{p}{1 + e\cos(u_1 - \omega)},$$

$$r_2 = \frac{p}{1 + e\cos(u_1 + \omega)},$$

$$\frac{1 + e\cos u_1\cos\omega - e\sin u_1\sin\omega}{1 + e\cos u_1\cos\omega + e\sin u_1\sin\omega} = -\frac{Z_1}{Z_2};$$

and, since $\cos u_1 = -e\cos\omega$,

$$\frac{\sin u_1 - e\sin\omega}{\sin u_1 + e\sin\omega} = -\frac{Z_1}{Z_2}.$$

Whence,

$$e\sin\omega = \frac{Z_2 + Z_1}{Z_2 - Z_1}\sin u_1,$$

which may be written in the form

$$e\sin\omega = \frac{2\sqrt{AB}}{A + B}\cdot\frac{Z_2 + Z_1}{Z_2 - Z_1}.$$

As it was found earlier from a consideration of the values A and B that

$$e\cos\omega = \frac{A - B}{A + B},$$

these two equations give all that is needed for a determination of e and ω. The values of A and B are taken from the curve, and the areas Z_1 and Z_2 are quickly integrated from the curve portions AaC and bBD by means of a planimeter (the latter area is considered negative in sign and the unit of area used is entirely immaterial as only the ratios of the areas are required).

At the time of passing through periastron $u = \omega$, whence from the fundamental equation

$$\frac{dz}{dt_p} = K(1 + e)\cos\omega.$$

Knowing K, e, and ω, determine this value, and the abscissa of the point on the curve which has the above value as ordinate will give the value of T when properly combined with the

epoch used for the beginning of the curve. As at the points A, B, and A_1, u equals 0, π, and 2π, respectively, and as ω is known, there will be no ambiguity as to the position of $u = \omega$.

We may instead determine the eccentric anomaly at the point C where u_1 is known, and then find the time from periastron, t_1, corresponding to this value of u_1 by the well-known formulæ

$$\tan\frac{E_1}{2} = \sqrt{\frac{1-e}{1+e}}\tan\frac{u_1-\omega}{2},$$

$$\mu = \frac{2\pi}{U},$$

$$T = t_1 - \frac{E_1 - e\sin E_1}{\mu}.$$

The equation for the mean daily motion may be transformed as follows:—

$$\mu = \frac{2\pi}{U} = \frac{f}{a^{3/2}} = \frac{A+B}{2}\cdot\frac{\sqrt{p}}{\sin i}\cdot\frac{1}{a^{3/2}};$$

from which the following equation for the product of the separately indeterminable a and $\sin i$ may be derived. The factor 86,400 must be introduced because the unit of time for A and B is the second, while for μ it is the day.

$$a\sin i = 86{,}400\frac{A+B}{2\mu}\sqrt{1-e^2} = [4.13833]\ K\,U\sqrt{1-e^2}.$$

In the use of the method of LEHMANN-FILHÉS slight inaccuracies in drawing the preliminary curve when the eccentricity is small are less troublesome than in the methods of superposition given before. For eccentricities under 0.10 all methods are apt to give too large values of the eccentricity, and it is well in such cases to reduce the first value found considerably and test a small value first.

EXAMPLE OF METHOD OF LEHMANN-FILHÉS (FROM FIG. 2).

$A = 46.3$	$K = \dfrac{A+B}{2} = 46.6$
$B = 46.9$	$Z_1 = +0.168$
$A + B = 93.2$	$Z_2 = -0.259$
$A - B = -0.6$	$Z_2 + Z_1 = -0.091$
	$Z_2 - Z_1 = -0.427$

$\log \sqrt{AB}$	1.6684	$\log Z_2 + Z_1$	8.9590n
colog (A + B)	8.0306	colog $Z_2 - Z_1$	0.3696n
log (A — B)	9.7782n	$\sin u_1$	0.0000
log 2	0.3010	$e \sin \omega$	9.3286
$\sin u_1$	0.0000	$e \cos \omega$	7.8808n (= — $\cos u_1$)
$\cos u_1$	7.8088	$\tan \omega$	1.4478n
u_1	89°.63	ω	92°.04
		$\log e$	9.3289
		e	0.21

$\log (1 + e)$	0.0828	const. log	4.1383
$\cos \omega$	8.5519n	K	1.6684
$\log K$	1.6684	U	2.0669
	0.3031n	$\sqrt{1 - e^2}$	9.9902
ordinate$_p$ = — 2.0^{km}		$a \sin i$	7.8638
t_p = 98.4 days			= 73,000,000^{km}

T = J. D. 2416457.75

(The longer method gives 6458.0.)

IMPROVED ELEMENTS.

Whatever the method used to determine the elements, it will always be necessary to test the elements as derived and make small changes in them before they can be regarded as a satisfactory representation of the observations. To do this a test ephemeris is rapidly computed for ten or twelve points of the curve. V being, as before, the velocity of the system as a whole, and placing $V' = V + K e \cos \omega = V + \frac{A - B}{2}$, the necessary formulæ for the ephemeris are

$$\frac{dz}{dt} = V' + K \cos u,$$

$$\tan \tfrac{1}{2} (u - \omega) = \sqrt{\frac{1 + e}{1 - e}} \tan \tfrac{1}{2} E,$$

$$M = E - e \sin E,$$

$$M = \mu (t - T).$$

Collecting the elements as derived by the method of LEHMANN-FILHÉS, with the necessary constants, we have:—

$U = 116.65$ days $\qquad \mu^\circ = 3^\circ.0861$

$e = 0.21 \qquad \log\sqrt{\dfrac{1+e}{1-e}} = 0.0926$

$T = 2416458.0 \qquad \dfrac{\mathrm{A}-\mathrm{B}}{2} = -0.3$

$K = 46.6 \qquad V' = +20.4$

$\omega = 92^\circ.04$

$V = +20.7^{\mathrm{km}}$

Then, at the point where $t = 20$ days, on Fig. 2, we have the following sample from the test ephemeris:—

$t = 2416496.0$

$t - T = 38.0 \qquad \tfrac{1}{2}(u - \omega) = 79^\circ.23$

$M = 148^\circ.13 \qquad u - \omega = 158.46$

$E = 153.50$ (From ÅSTRAND's Hülfstafeln) $\qquad u = 250.50$

$\tan \tfrac{1}{2} E = 0.6281 \qquad \text{nat} \cos u = -0.334$

$\tan \tfrac{1}{2}(u - \omega) = 0.7207 \qquad V' + K \cos u = dz/dt = +4.8^{\mathrm{km}}$

In this way a test ephemeris was rapidly computed for the points 0, 10, 20 days, etc., of Fig. 2. The resulting curve, to save confusion, is not drawn in, but its position is represented by the heavy black dots. A study of the discrepancies shows that e is a little too large, the branch on the apastron side being somewhat too sloping, while the other slope is a little too steep. When e is changed we shall also need to make small changes in T and ω. Making one or two changes in this way, and testing at critical points of the curve, the following elements were finally decided upon as best satisfying the observations:—

$$
\begin{aligned}
V &= +21.9^{\mathrm{km}} \\
U &= 116.65 \text{ days} \\
e &= 0.19 \\
K &= 46.5 \\
\omega &= 96^\circ.23 \\
T &= \text{J. D. } 2416459.0 \\
a \sin i &= 73{,}000{,}000^{\mathrm{km}}
\end{aligned}
$$

The correction to the value of V was found last of all from the residuals of the final ephemeris by the simple formula

$\frac{[v]}{n}$, where n is the number of observations and v the residual, o — c. The residuals from the final ephemeris and the final curve may be found in *Lick Observatory Bulletin,* No. 122, 1907.

Combining the best results from the methods of SCHWARZSCHILD and ZURHELLEN, we would have the following elements:—

$$T = 2416458.15$$
$$\omega = 94.4$$
$$e = 0.18$$
$$K = 46.6$$
$$V' = +19.8$$
$$\log \sqrt{\frac{1+e}{1-e}} = 0.0790$$

A test curve from these elements was also computed, and its position is represented by the small crosses at the points 5, 15, 25, etc., days. These elements are seen also to need small corrections, but on the whole are rather nearer the observation curve than are the values secured by the method of LEHMANN-FILHÉS, as the position of periastron is about the most favorable for the determination of the eccentricity by ZURHELLEN'S methods of tangents.

With some experience it is possible to secure elements which would be little, if any, bettered by a least-square solution, unless a large number of well-determined velocities are available, extending over a considerable interval of time. For completeness, however, the least-squares formulæ are given here as derived by LEHMANN-FILHÉS:—

$$\delta \frac{dz}{dt} = (\cos u + e \cos \omega)\ \delta K$$

$$+ K\ \left[\cos \omega - \frac{\sin u \sin v}{1 - e^2} (2 + e \cos v)\right]\ \delta e$$

$$- K\ (\sin u + e \sin \omega)\ \delta\,\omega$$

$$- K \sin u\ (1 + e \cos v)^2.\ (t - T)\ \frac{1}{(1 - e^2)^{\frac{3}{2}}}\ \delta\,\mu$$

$$+ \sin u\ (1 + e \cos v)^2\ \frac{K\mu}{(1 - e^2)^{\frac{3}{2}}}\ \delta T.$$

In case both spectra are visible and the motion of one star is determined with reference to the other $f = k\sqrt{m + m'}$, and an equation for the relation of the masses is found from the relation

$$\mu = \frac{k\sqrt{m + m'}}{a^{\frac{3}{2}}},$$

giving

$$m + m' = \frac{\mu^2 (a \sin i)^3}{k^2 \sin^3 i},$$

where A, B, and $a \sin i$ are to be expressed in terms of the mean distance of the earth from the Sun. If the velocity of the center of mass of such a system has also been determined, then from this the relation of both masses is known, for each mass may then be represented separately in the form

$$\frac{\text{constant}}{\sin^3 i}.$$

Further data as to methods of treating the comparatively rare cases where both spectra are measurable are given in ZURHELLEN's last paper.

In the still rarer cases where both visual and spectrographic observations of a system are at hand, valuable results as to the parallax and relative masses of such systems may be secured. Reference may be made here to Professor HUSSEY's determination of the parallax of *δ Equulei* (*Lick Observatory Bulletin,* No. 32), Professor WRIGHT's value of the parallax of *α Centauri* (*Lick Observatory Bulletin,* No. 60), and to Dr. CAMPBELL's discussion of the variable radial velocity of *Sirius* (*Lick Observatory Bulletin,* No. 70).

THE D. O. MILLS EXPEDITION,
SANTIAGO, CHILE, October, 1907.

ECLIPSES AND TRANSITS OF THE SATELLITES OF *SATURN* OCCURRING IN THE YEAR 1908.

By Hermann Struve.

For the present year the cycle of eclipses and transits of the satellites of *Saturn* extends over all inner satellites, including *Rhea*, the latter being eclipsed only during the earlier months, till September, before the opposition of the planet.

An interesting feature of the present cycle of eclipses is, that the disappearances of the satellites before opposition occur generally at a greater distance from the limb of *Saturn* than the reappearances after opposition, and are therefore easier to observe. In the preceding years, before the Earth had passed the plane of the ring, the contrary was the case—i. e. the reappearances could be observed at the greater distance from the planet.

Of particular interest is the remark, that in the case of *Rhea*, describing only a small chord through the shadow-cone of the planet, both phenomena, the disappearance and the reappearance, occur geocentrically outside of the limb, and can be observed together. And as the predicted times of disappearance and reappearance depend chiefly and in a very high degree on the assumed polar diameter of the planet, the observation of these phenomena will be of great value for the derivation of this constant, unknown at present to some tenths of a second. To direct the attention of the observers to these interesting observations, I have first collected the data for the eclipses of *Rhea*, which can be observed also with smaller instruments.

The tables of the eclipses of the other satellites are arranged in the same manner as in the preceding years.[1] For these satellites only the disappearances are visible before opposition, and only the reappearances after opposition. The first column contains the day of the month, the second the eclipsed satellite, the third the Greenwich time of disappearance or reappear-

[1] See these *Publications*, Vol. XVIII, p. 203; Vol. XIX, p. 125.

ance, and the last, headed *s* and *p*, the geocentric place of the satellite at the given time—i. e. the distance of the satellite from the limb of the planet, and the position-angle, counted from the north point of the minor axis of the disk to the east. The duration of the appearances may be, in the case of *Tethys* and *Dione*, two or three minutes, in the case of *Rhea*, passing near the surface of the shadow-cone, much longer. The time of first or last seeing must be noted, and also the times of equal brightness by comparison with the other satellites.

Finally are added the approximate Greenwich times, when the shadows of the satellites *Tethys*, *Dione*, and *Rhea* cross the minor axis of the disk, together with their distances from the center of the disk at the time of conjunction. Possessors of powerful instruments searching for the shadows may decide the question, whether they are discernible on the disk of the planet.

The present opposition of *Saturn* will be the last for many years, where the brighter satellites will be eclipsed. In the next year only eclipses of *Enceladus* and *Mimas* will take place. On account of the important conclusions, to which the observations of the eclipses lead, it is to be hoped that the favorable opportunity will not be lost, and that the observers will duly attend to these rare and interesting phenomena.

In the preparation of the following tables I was kindly assisted by Dr. NEUGEBAUER:—

ROYAL OBSERVATORY, BERLIN, April, 1908.

ECLIPSES OF *RHEA*.

s and *p* denote the geocentric place of *Rhea* at the time of disappearance or reappearance—i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the east.

1908.		Gr. M. T.		*s*.	*p*.	dt for da = 0″.1	Meridian Passage.
June 15.	Disapp.	17^h	40^m	7″.1	232°	∓ 2^m	19^h 0^m
15.	Reapp.	20	7	1 .9	189		
20.	Disapp.	6	9	7 .2	232	∓ 2	18 42
20.	Reapp.	8	32	2 .1	191		
24.	Disapp.	18	38	7 .4	231	∓ 2	18 27
24.	Reapp.	20	57	2 .3	192		
29.	Disapp.	7	7	7 .5	231	∓ 2	18 8
29.	Reapp.	9	22	2 .5	193		
July 3.	Disapp.	19	36	7 .5	230	∓ 2	17 53
3.	Reapp.	21	47	2 .6	193		
8.	Disapp.	8	5	7 .5	230	∓ 3	17 34
8.	Reapp.	10	13	2 .7	194		
12.	Disapp.	20	34	7 .4	229	∓ 3	17 18
12.	Reapp.	22	38	2 .8	194		
17.	Disapp.	9	4	7 .3	228	∓ 3	16 59
17.	Reapp.	11	2	2 .8	195		
21.	Disapp.	21	33	7 .1	228	∓ 3	16 43
21.	Reapp.	23	27	2 .8	195		
26.	Disapp.	10	3	6 .8	227	∓ 3	16 24
26.	Reapp.	11	52	2 .8	195		
30.	Disapp.	22	32	6 .5	226	∓ 3	16 8
31.	Reapp.	0	16	2 .7	195		
Aug. 4.	Disapp.	11	3	6 .2	225	∓ 3	15 48
4.	Reapp.	12	40	2 .7	195		
8.	Disapp.	23	33	5 .8	224	∓ 4	15 32
9.	Reapp.	1	5	2 .6	195		
13.	Disapp.	12	3	5 .3	222	∓ 4	15 11
13.	Reapp.	13	28	2 .5	194		
18.	Disapp.	0	34	4 .8	220	∓ 4	14 51
18.	Reapp.	1	52	2 .3	194		
22.	Disapp.	13	6	4 .3	218	∓ 5	14 35
22.	Reapp.	14	15	2 .1	193		
27.	Disapp.	1	38	3 .6	215	∓ 6	14 14
27.	Reapp.	2	38	1 .9	193		
31.	Disapp.	14	11	3 .0	211	∓ 7	13 57
31.	Reapp.	14	59	1 .8	193		
Sept. 5.	Disapp.	2	46	2 .4	207	∓ 8	13 37
5.	Reapp.	3	19	1 .6	193		
9.	Eclipse? (Heliocentric conj.)	15	29	1 .5	198	∓ 16	13 20
14.	Eclipse? (Heliocentric conj.)	3	57	...	...	....	12 59
18.	Eclipse? (Heliocentric conj.)	16	24	...	...	....	12 42

In computing these data, the values of the semi-axes of the planet were assumed to be: $a = 8''.735$, $b = 7''.825$, at the mean distance. On this supposition the latest eclipse of *Rhea* will take place September 5th. Supposing the semi-axes 0″.1 larger, the end of the cycle of eclipses falls on the date Sep-

tember 9th, and the times of disappearance and reappearance will change by the quantities, expressed in minutes, given in the column headed "dt for da = 0″.1." The predicted times might therefore be changed greatly by the size of the planet, by the penumbra, etc., which could here not be taken into account.

It will be worth while to watch the satellite until its latest eclipses, in September, and to ascertain precisely the end of their cycle. For these observations, also, photometers may be used with success, as the brightness of the satellite will vary slowly.

ECLIPSES OF THE INNER SATELLITES OF *SATURN*, 1908.

Disappearance before opposition.

s and *p* denote the geocentric place of the satellite at the time of its disappearance—i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the east.

1908.		Gr. M. T.	*s.*	*p.*
July 1.	Mi.	23h 4m	2″.6	256°
	Di.	23 10	5 .7	239
2.	Te.	11 34	4 .5	243
	En.	14 0	3 .6	248
	Mi.	21 41	2 .6	256
3.	Rh.	19 36 D	7 .5	230
	Mi.	20 18	2 .6	256
	Rh.	21 47 R	2 .6	193
	En.	22 54	3 .6	248
4.	Te.	8 52	4 .5	243
	Di.	16 52	5 .7	239
	Mi.	18 56	2 .6	256
5.	En.	7 47	3 .6	248
	Mi.	17 33	2 .6	256
6.	Te.	6 11	4 .5	243
	Mi.	16 10	2 .6	256
	En.	16 40	3 .6	248
7.	Di.	10 34	5 .7	239
	Mi.	14 47	2 .6	256
8.	En.	1 33	3 .6	248
	Te.	3 30	4 .5	243
	Rh.	8 5 D	7 .5	230
	Rh.	10 13 R	2 .7	194
	Mi.	13 24	2 .6	256
9.	En.	10 26	3 .6	248
	Mi.	12 1	2 .6	256
10.	Te.	0 49	4 .5	243
July 10.	Di.	4h 16m	5″.7	239°
	Mi.	10 38	2 .6	256
	En.	19 20	3 .6	248
11.	Mi.	9 16	2 .6	256
	Te.	22 8	4 .5	243
12.	En.	4 13	3 .6	248
	Mi.	7 53	2 .6	256
	Rh.	20 34 D	7 .4	229
	Di.	21 58	5 .7	238
	Rh.	22 38 R	2 .8	194
13.	Mi.	5 30	2 .6	256
	En.	13 6	3 .6	248
	Te.	19 27	4 .5	242
14.	Mi.	4 7	2 .6	256
	En.	21 59	3 .6	248
15.	Mi.	2 44	2 .6	256
	Di.	15 40	5 .6	238
	Te.	16 46	4 .5	242
16.	Mi.	1 21	2 .6	255
	En.	6 52	3 .6	248
17.	Mi.	0 59	2 .6	255
	Rh.	9 4 D	7 .3	228
	Rh.	11 2 R	2 .8	195
	Te.	14 4	4 .5	242
	En.	15 46	3 .6	248
	Mi.	23 36	2 .6	255
18.	Di.	9 22	5 .6	238

1908.		Gr. M. T.	*s.*	*p.*
July 18.	Mi.	$22^h\ 13^m$	2″.6	255°
19.	En.	0 39	3 .6	248
	Te.	11 23	4 .4	242
	Mi.	20 50	2 .6	255
20.	En.	9 32	3 .6	248
	Mi.	19 27	2 .6	255
21.	Di.	3 4	5 .5	238
	Te.	8 42	4 .4	242
	Mi.	18 5	2 .6	255
	En.	18 25	3 .6	248
	Rh.	21 33 D	7 .1	228
	Rh.	23 27 R	2 .8	195
22.	Mi.	16 42	2 .6	255
23.	En.	3 18	3 .5	248
	Te.	6 1	4 .4	242
	Mi.	15 19	2 .6	255
	Di.	20 46	5 .5	238
24.	En.	12 12	3 .5	248
	Mi.	13 56	2 .6	255
25.	Te.	3 20	4 .3	242
	Mi.	12 33	2 .6	255
	En.	21 5	3 .5	248
26.	Rh.	10 3 D	6 .8	227
	Mi.	11 11	2 .5	255
	Rh.	11 52 R	2 .8	195
	Di.	14 29	5 .4	237
27.	Te.	0 38	4 .3	241
	En.	5 58	3 .5	248
	Mi.	9 48	2 .5	255
28.	Mi.	8 25	2 .5	255
	En.	14 51	3 .4	248
	Te.	21 57	4 .2	241
29.	Mi.	7 2	2 .5	254
	Di.	8 11	5 .3	237
	En.	23 44	3 .4	248
30.	Mi.	5 39	2 .5	254
	Te.	19 16	4 .2	241
	Rh.	22 32 D	6 .5	226
31.	Rh.	0 16 R	2 .7	195
	Mi.	4 17	2 .5	254
	En.	8 38	3 .3	247
Aug. 1.	Di.	1 53	5 .2	237
	Mi.	2 54	2 .5	254
	Te.	16 35	4 .1	241
	En.	17 31	3 .3	247
2.	Mi.	1 31	2 .5	254
3.	Mi.	0 8	2 .4	254

1908.		Gr. M. T.	*s.*	*p.*
Aug. 3.	En.	$2^h\ 24^m$	3″.3	247°
	Te.	13 54	4 .0	241
	Di.	19 35	5 .0	236
	Mi.	22 46	2 .4	254
4.	Rh.	11 3 D	6 .2	225
	En.	11 17	3 .2	247
	Rh.	12 40 R	2 .7	195
	Mi.	21 23	2 .4	254
5.	Te.	11 13	4 .0	241
	Mi.	20 0	2 .4	254
	En.	20 11	3 .2	247
6.	Di.	13 18	4 .8	236
	Mi.	18 37	2 .3	254
7.	En.	5 4	3 .2	247
	Te.	8 32	3 .9	241
	Mi.	17 14	2 .3	254
8.	En.	13 57	3 .1	247
	Mi.	15 52	2 .3	254
	Rh.	23 33 D	5 .8	224
9.	Rh.	1 5 R	2 .6	195
	Te.	5 50	3 .8	240
	Di.	7 0	4 .6	236
	Mi.	14 29	2 .3	254
	En.	22 50	3 .1	247
10.	Mi.	13 6	2 .2	254
11.	Te.	3 9	3 .7	240
	En.	7 44	3 .0	247
	Mi.	11 43	2 .2	253
12.	Di.	0 42	4 .4	236
	Mi.	10 21	2 .2	253
	En.	16 37	3 .0	247
13.	Te.	0 28	3 .6	240
	Mi.	8 58	2 .2	253
	Rh.	12 3 D	5 .3	222
	Rh.	13 28 R	2 .5	194
14.	En.	1 30	2 .9	247
	Mi.	7 35	2 .1	253
	Di.	18 24	4 .2	235
	Te.	21 47	3 .5	240
15.	Mi.	6 12	2 .1	253
	En.	10 23	2 .9	247
16.	Mi.	4 50	2 .1	253
	Te.	19 6	3 .4	240
	En.	19 16	2 .8	247
17.	Mi.	3 27	2 .1	253
	Di.	12 7	4 .0	235
18.	Rh.	0 34 D	4 .8	220

1908.		Gr. M. T.		*s.*	*p.*
Aug. 18.	Rh.	1^h	52^m R	2″.3	194°
	Mi.	2	4	2 .1	253
	En.	4	10	2 .7	247
	Te.	16	25	3 .3	240
19.	Mi.	0	41	2 .0	253
	En.	13	3	2 .7	247
	Mi.	23	19	2 .0	253
20.	Di.	5	49	3 .8	234
	Te.	13	44	3 .2	239
	Mi.	21	56	2 .0	253
	En.	21	56	2 .6	247
21.	Mi.	20	33	1 .9	253
22.	En.	6	49	2 .5	247
	Te.	11	3	3 .0	239
	Rh.	13	6 D	4 .3	218
	Rh.	14	15 R	2 .1	193
	Mi.	19	10	1 .9	253
	Di.	23	31	3 .6	234
23.	En.	15	43	2 .5	247
	Mi.	17	48	1 .8	252
24.	Te.	8	22	2 .9	239
	Mi.	16	25	1 .8	252
25.	En.	0	36	2 .4	247
	Mi.	15	2	1 .7	252
	Di.	17	14	3 .4	234
26.	Te.	5	41	2 .8	239
	En.	9	29	2 .4	246
	Mi.	13	40	1 .7	252
27.	Rh.	1	38 D	3 .6	215
	Rh.	2	38 R	1 .9	193
	Mi.	12	17	1 .7	252
	En.	18	22	2 .3	246
28.	Te.	3	0	2 .7	238
	Mi.	10	54	1 .7	252
	Di.	10	56	3 .2	233
29.	En.	3	16	2 .2	246
	Mi.	9	32	1 .6	252
30.	Te.	0	19	2 .5	238
	Mi.	8	9	1 .6	252
	En.	12	9	2 .1	246
31.	Di.	4	38	3 .0	233
	Mi.	6	46	1 .5	252
	Rh.	14	11 D	3 .0	211
	Rh.	14	59 R	1 .8	193
	En.	21	2	2 .0	246
	Te.	21	38	2 .4	238
Sept. 1.	Mi.	5	23	1 .5	252

1908.		Gr. M. T.		*s.*	*p.*
Sept. 2.	Mi.	4^h	1^m	1″.5	252°
	En.	5	56	1 .9	246
	Te.	18	57	2 .2	238
	Di.	22	21	2 .8	232
3.	Mi.	2	38	1 .4	252
	En.	14	49	1 .8	246
4.	Mi.	1	15	1 .4	251
	Te.	16	16	2 .1	237
	En.	23	42	1 .8	246
	Mi.	23	53	1 .4	251
5.	Rh.	2	46 D	2 .4	206
	Rh.	3	19 R	1 .6	193
	Di.	16	3	2 .5	231
	Mi.	22	30	1 .3	251
6.	En.	8	36	1 .7	246
	Te.	13	35	1 .9	237
	Mi.	21	7	1 .3	251
7.	En.	17	29	1 .6	246
	Mi.	19	44	1 .2	251
8.	Di.	9	46	2 .2	231
	Te.	10	54	1 .8	237
	Mi.	18	22	1 .2	251
9.	En.	2	22	1 .6	246
	Rh.	15	29	Eclipse?	
	Mi.	16	59	1 .1	251
10.	Te.	8	13	1 .6	236
	En.	11	16	1 .5	246
	Mi.	15	36	1 .1	251
11.	Di.	3	28	1 .9	230
	Mi.	14	14	1 .0	251
	En.	20	9	1 .4	246
12.	Te.	5	32	1 .5	236
	Mi.	12	51	1 .0	251
13.	En.	5	2	1 .3	246
	Mi.	11	28	0 .9	250
	Di.	21	11	1 .6	229
14.	Te.	2	51	1 .4	236
	Rh.	3	57	Eclipse?	
	Mi.	10	6	0 .9	250
	En.	13	56	1 .2	246
15.	Mi.	8	43	0 .8	250
	En.	22	49	1 .1	246
16.	Te.	0	10	1 .2	235
	Mi.	7	20	0 .8	250
	Di.	14	53	1 .3	228
17.	Mi.	5	58	0 .7	250
	En.	7	42	1 .0	245

1908.		Gr. M. T.	s.	p.
Sept. 17.	Te.	$21^h 29^m$	1".0	235°
18.	Mi.	4 35	0 .7	250
	Rh.	16 24	Eclipse?	
	En.	16 36	0 .9	245
19.	Mi.	3 12	0 .6	250
	Di.	8 36	1 .0	228
	Te.	18 48	0 .9	235
20.	En.	1 29	0 .8	245
	Mi.	1 50	0 .6	250
21.	Mi.	0 27	0 .5	250
	En.	10 22	0 .7	245
	Te.	16 7	0 .7	234
	Mi.	23 4	0 .5	249
22.	Di.	2 18	0 .7	227
	En.	19 16	0 .6	245
	Mi.	21 42	0 .4	249
23.	Te.	13 26	0 .6	234
	Mi.	20 19	0 .4	249

1908.		Gr. M. T.	s.	p.
Sept. 24.	En.	$4^h 9^m$	0".5	245°
	Mi.	18 56	0 .3	249
	Di.	20 1	0 .4	226
25.	Te.	10 45	0 .4	234
	En.	13 2	0 .4	245
	Mi.	17 34	0 .3	249
26.	Mi.	16 11	0 .2	249
	En.	21 56	0 .3	245
27.	Te.	8 4	0 .2	233
	Di.	13 44	0 .1	225
	Mi.	14 48	0 .2	249
28.	En.	6 49	0 .2	245
	Mi.	13 26	0 .1	249
29.	Te.	5 23	0 .1	233
	Mi.	12 3	0 .1	249
	En.	15 42	0 .1	245
30.	Mi.	10 41	0 .0	248

Reappearance after opposition.

s and *p* denote the geocentric place of the satellite at the time of its reappearance—i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the east.

1908.		Gr. M. T.	s.	p.
Oct. 1.	En.	$2^h 57^m$	0".0	115°
	Mi.	11 24	0 .0	113
2.	Mi.	10 2	0 .0	113
	En.	11 50	0 .0	115
3.	Mi.	8 39	0 .0	113
	En.	20 44	0 .1	115
4.	Mi.	7 16	0 .0	113
	Te.	23 30	0 .0	128
5.	En.	5 37	0 .1	114
	Mi.	5 53	0 .1	113
6.	Mi.	4 31	0 .1	112
	En.	14 30	0 .2	114
	Te.	20 49	0 .0	127
7.	Mi.	3 8	0 .1	112
	En.	23 24	0 .3	113
8.	Mi.	1 45	0 .2	112
	Di.	14 37	0 .0	133
	Te.	18 7	0 .1	127
9.	Mi.	0 22	0 .2	112
	En.	8 17	0 .3	113
	Mi.	23 0	0 .2	112
10.	Te.	15 26	0 .1	126
	En.	17 10	0 .4	113

1908.		Gr. M. T.	s.	p.
Oct. 10.	Mi.	$21^h 37^m$	0".3	112°
11.	Di.	8 18	0 .0	132
	Mi.	20 14	0 .3	112
12.	En.	2 3	0 .4	112
	Te.	12 45	0 .2	125
	Mi.	18 51	0 .3	111
13.	En.	10 57	0 .5	112
	Mi.	17 29	0 .4	111
14.	Di.	2 0	0 .1	130
	Te.	10 3	0 .3	124
	Mi.	16 6	0 .4	111
	En.	19 50	0 .5	112
15.	Mi.	14 43	0 .4	111
16.	En.	4 43	0 .5	111
	Te.	7 22	0 .3	123
	Mi.	13 20	0 .4	111
	Di.	19 41	0 .2	129
17.	Mi.	11 58	0 .5	110
	En.	13 37	0 .6	111
18.	Te.	4 41	0 .4	123
	Mi.	10 35	0 .5	110
	En.	22 30	0 .6	111
19.	Mi.	9 12	0 .5	110

1908.		Gr. M. T.		s.	p.
Oct. 19.	Di.	13^h	23^m	$0''.3$	128°
20.	Te.	1	59	0 .4	122
	En.	7	23	0 .7	110
	Mi.	7	50	0 .5	110
21.	Mi.	6	27	0 .6	110
	En.	16	17	0 .7	110
	Te.	23	18	0 .5	122
22.	Mi.	5	4	0 .6	110
	Di.	7	4	0 .3	127
23.	En.	1	10	0 .7	110
	Mi.	3	42	0 .6	110
	Te.	20	37	0 .5	121
24.	Mi.	2	19	0 .7	109
	En.	10	3	0 .8	109
25.	Di.	0	46	0 .4	126
	Mi.	0	56	0 .7	109
	Te.	17	56	0 .6	121
	En.	18	57	0 .8	109
	Mi.	23	33	0 .7	109
26.	Mi.	22	11	0 .7	109
27.	En.	3	50	0 .9	109
	Te.	15	14	0 .6	120
	Di.	18	27	0 .5	124
	Mi.	20	48	0 .8	109
28.	En.	12	43	0 .9	109
	Mi.	19	25	0 .8	109
29.	Te.	12	33	0 .7	120
	Mi.	18	3	0 .8	109
	En.	21	37	1 .0	109
30.	Di.	12	9	0 .6	123
	Mi.	16	40	0 .8	109
31.	En.	6	30	1 .0	108
	Te.	9	52	0 .7	119
	Mi.	15	17	0 .8	108
Nov. 1.	Mi.	13	54	0 .9	108
	En.	15	24	1 .1	108
2.	Di.	5	51	0 .7	122
	Te.	7	10	0 .8	119
	Mi.	12	32	0 .9	108
3.	En.	0	17	1 .1	108
	Mi.	11	9	0 .9	108
4.	Te.	4	29	0 .8	119
	En.	9	10	1 .2	108
	Mi.	9	46	0 .9	108
	Di.	23	32	0 .8	122
5.	Mi.	8	24	1 .0	108
	En.	18	4	1 .2	108

1908.		Gr. M. T.		s.	p.
Nov. 6.	Te.	1^h	48^m	$0''.9$	118°
	Mi.	7	1	1 .0	108
7.	En.	2	57	1 .3	107
	Mi.	5	38	1 .0	108
	Di.	17	14	0 .9	121
	Te.	23	6	0 .9	118
8.	Mi.	4	16	1 .0	107
	En.	11	50	1 .3	107
9.	Mi.	2	53	1 .1	107
	Te.	20	25	1 .0	118
	En.	20	44	1 .4	107
10.	Mi.	1	30	1 .1	107
	Di.	10	55	0 .9	120
11.	Mi.	0	8	1 .1	107
	En.	5	37	1 .4	107
	Te.	17	44	1 .0	117
	Mi.	22	45	1 .2	107
12.	En.	14	30	1 .5	107
	Mi.	21	22	1 .2	107
13.	Di.	4	37	1 .0	119
	Te.	15	3	1 .1	117
	Mi.	20	0	1 .2	107
	En.	23	24	1 .5	107
14.	Mi.	18	37	1 .2	107
15.	En.	8	17	1 .5	106
	Te.	12	22	1 .1	117
	Mi.	17	14	1 .3	107
	Di.	22	18	1 .1	119
16.	Mi.	15	52	1 .3	106
	En.	17	11	1 .6	106
17.	Te.	9	40	1 .2	117
	Mi.	14	29	1 .3	106
18.	En.	2	4	1 .6	106
	Mi.	13	6	1 .3	106
	Di.	16	0	1 .1	118
19.	Te.	6	59	1 .2	116
	En.	10	57	1 .6	106
	Mi.	11	44	1 .4	106
20.	Mi.	10	21	1 .4	106
	En.	19	51	1 .7	106
21.	Te.	4	18	1 .3	116
	Mi.	8	58	1 .4	106
	Di.	9	41	1 .2	118
22.	En.	4	44	1 .7	106
	Mi.	7	35	1 .4	106
23.	Te.	1	37	1 .3	116
	Mi.	6	13	1 .4	106

1908.		Gr. M. T.		s.	p.	1908.		Gr. M. T.		s.	p.
No. 23.	En.	13^h	38^m	1″.7	106°	Dec. 11.	Mi.	4^h	2^m	1″.6	104°
24.	Di.	3	23	1 .2	118		En.	9	12	2 .0	105
	Mi.	4	50	1 .5	106		Te.	22	45	1 .5	115
	En.	22	31	1 .8	106	12.	Mi.	2	39	1 .6	104
	Te.	22	56	1 .4	116		En.	18	5	2 .0	105
25.	Mi.	3	27	1 .5	105	13.	Mi.	1	16	1 .6	104
26.	Mi.	2	5	1 .5	105		Di.	7	12	1 .2	118
	En.	7	24	1 .8	106		Te.	20	3	1 .5	115
	Te.	20	14	1 .2	118		Mi.	23	54	1 .6	104
	Di.	21	4	1 .4	116	14.	En.	2	59	2 .0	105
27.	Mi.	0	42	1 .5	105		Mi.	22	31	1 .6	104
	En.	16	18	1 .9	106	15.	En.	11	52	2 .0	105
	Mi.	23	19	1 .5	105		Te.	17	22	1 .5	116
28.	Te.	17	33	1 .4	115		Mi.	21	8	1 .6	104
	Mi.	21	57	1 .5	105	16.	Di.	0	54	1 .2	119
29.	En.	1	11	1 .9	105		Mi.	19	46	1 .6	104
	Di.	14	46	1 .2	118		En.	20	46	2 .0	106
	Mi.	20	34	1 .5	105	17.	Te.	14	41	1 .5	116
30.	En.	10	5	1 .9	105		Mi.	18	23	1 .6	104
	Te.	14	52	1 .4	115	18.	En.	5	39	2 .0	106
	Mi.	19	11	1 .5	105		Mi.	17	0	1 .6	104
Dec. 1.	Mi.	17	49	1 .6	105		Di.	18	35	1 .1	119
	En.	18	58	1 .9	105	19.	Te.	12	0	1 .4	116
2.	Di.	8	27	1 .2	118		En.	14	32	2 .0	106
	Te.	12	11	1 .4	115		Mi.	15	38	1 .6	104
	Mi.	16	26	1 .6	105	20.	Mi.	14	15	1 .6	104
3.	En.	3	51	1 .9	105		En.	23	26	2 .0	106
	Mi.	15	3	1 .6	105	21.	Te.	9	18	1 .4	116
4.	Te.	9	30	1 .4	115		Di.	12	16	1 .1	120
	En.	12	45	1 .9	105		Mi.	12	52	1 .6	104
	Mi.	13	41	1 .6	105	22.	En.	8	19	2 .0	106
5.	Di.	2	8	1 .2	118		Mi.	11	30	1 .6	104
	Mi.	12	18	1 .6	105	23.	Te.	6	37	1 .4	116
	En.	21	38	1 .9	105		Mi.	10	7	1 .6	104
6.	Te.	6	48	1 .4	115		En.	17	13	2 .0	106
	Mi.	10	55	1 .6	105	24.	Di.	5	58	1 .0	120
7.	En.	6	32	2 .0	105		Mi.	8	44	1 .6	104
	Mi.	9	33	1 .6	105	25.	En.	2	6	2 .0	106
	Di.	19	50	1 .2	118		Te.	3	56	1 .4	117
8.	Te.	4	7	1 .4	115		Mi.	7	22	1 .6	104
	Mi.	8	10	1 .6	104	26.	Mi.	5	59	1 .7	104
	En.	15	25	2 .0	105		En.	11	0	2 .0	106
9.	Mi.	6	47	1 .6	104		Di.	23	39	1 .0	121
10.	En.	0	18	2 .0	105	27.	Te.	1	15	1 .4	117
	Te.	1	26	1 .5	115		Mi.	4	36	1 .7	104
	Mi.	5	24	1 .6	104		En.	19	53	2 .0	106
	Di.	13	31	1 .2	118	28.	Mi.	3	13	1 .7	104

1908.		Gr. M. T.	s.	p.	1909.		Gr. M. T.	s.	p.
Dec. 28.	Te.	22^h 34^m	1″.4	117°	Jan. 13.	Te.	1^h 4^m	1″.2	120°
29.	Mi.	1 51	1 .7	104		Mi.	3 47	1 .6	104
	En.	4 47	2 .0	106		En.	6 34	1 .8	108
	Di.	17 20	0 .9	121	14.	Mi.	2 24	1 .6	104
30.	Mi.	0 28	1 .7	104		En.	15 28	1 .8	108
	En.	13 40	2 .0	106		Te.	22 22	1 .1	120
	Te.	19 52	1 .4	117	15.	Mi.	1 2	1 .6	104
	Mi.	23 5	1 .7	104		Di.	3 24	0 .3	127
31.	Mi.	21 43	1 .7	104		Mi.	23 39	1 .6	104
	En.	22 34	1 .9	106	16.	En.	0 21	1 .8	108
1909.						Te.	19 41	1 .1	121
Jan. 1.	Di.	11 1	0 .8	122		Mi.	22 16	1 .6	104
	Te.	17 11	1 .3	118	17.	En.	9 14	1 .7	108
	Mi.	20 20	1 .7	104		Mi.	20 53	1 .5	104
2.	En.	7 27	1 .9	106		Di.	21 4	0 .2	129
	Mi.	18 57	1 .7	104	18.	Te.	17 0	1 .0	121
3.	Te.	14 30	1 .3	118		En.	18 8	1 .7	108
	En.	16 20	1 .9	107		Mi.	19 31	1 .5	104
	Mi.	17 34	1 .7	104	19.	Mi.	18 8	1 .5	104
4.	Di.	4 42	0 .7	123	20.	En.	3 1	1 .7	109
	Mi.	16 12	1 .7	104		Te.	14 18	1 .0	122
5.	En.	1 14	1 .9	107		Di.	14 44	0 .1	131
	Te.	11 48	1 .3	119		Mi.	16 45	1 .5	104
	Mi.	14 49	1 .7	104	21.	En.	11 55	1 .7	109
6.	En.	10 7	1 .8	107		Mi.	15 22	1 .5	104
	Mi.	13 26	1 .7	104	22.	Te.	11 37	0 .9	123
	Di.	22 22	0 .6	124		Mi.	14 0	1 .5	104
7.	Te.	9 7	1 .3	119		En.	20 48	1 .6	109
	Mi.	12 4	1 .7	104	23.	Di.	8 24	0 .0	133
	En.	19 1	1 .8	107		Mi.	12 37	1 .5	104
8.	Mi.	10 41	1 .7	104	24.	En.	5 42	1 .6	110
9.	En.	3 54	1 .8	107		Te.	8 56	0 .9	123
	Te.	6 26	1 .2	119		Mi.	11 14	1 .5	104
	Mi.	9 18	1 .6	104	25.	Mi.	9 51	1 .5	104
	Di.	16 3	0 .5	125		En.	14 35	1 .6	110
10.	Mi.	7 55	1 .6	104	26.	Te.	6 15	0 .8	124
	En.	12 47	1 .8	107		Mi.	8 28	1 .5	104
11.	Te.	3 45	1 .2	120		En.	23 28	1 .5	110
	Mi.	6 33	1 .6	104	27.	Mi.	7 6	1 .5	104
	En.	21 41	1 .8	108	28.	Te.	3 33	0 .8	124
12.	Mi.	5 10	1 .6	104		Mi.	5 43	1 .5	104
	Di.	9 44	0 .4	126		En.	8 22	1 .5	110

SHADOWS OF THE SATELLITES *TETHYS, DIONE, RHEA.*

Crossing the minor axis of the disk at the distance y from the center.

1908.		Gr. M. T.	y	
July 1.	Te.	$14^h.3$	$4''.5$	North
	Rh.	14 .5	6 .8	
3.	Di.	9 .4	5 .3	
	Te.	11 .6	4 .5	
5.	Te.	8 .9	4 .6	
6.	Rh.	3 .0	6 .9	
	Di.	3 .1	5 .3	
7.	Te.	6 .2	4 .7	
8.	Di.	20 .8	5 .4	
9.	Te.	3 .6	4 .7	
10.	Rh.	15 .4	7 .1	
11.	Te.	0 .9	4 .8	
	Di.	14 .5	5 .5	
12.	Te.	22 .2	4 .8	
14.	Di.	8 .2	5 .5	
	Te.	19 .5	4 .9	
15.	Rh.	3 .9	7 .2	
16.	Te.	16 .8	4 .9	
17.	Di.	1 .9	5 .6	
18.	Te.	14 .1	5 .0	
19.	Rh.	16 .3	7 .3	
	Di.	19 .6	5 .6	
20.	Te.	11 .4	5 .0	
22.	Te.	8 .7	5 .1	
	Di.	13 .3	5 .7	
24.	Rh.	4 .8	7 .4	
	Te.	6 .0	5 .1	
25.	Di.	7 .0	5 .8	
26.	Te.	3 .3	5 .2	
28.	Te.	0 .6	5 .2	
	Di.	0 .6	5 .8	
	Rh.	17 .2	7 .6	
29.	Te.	22 .0	5 .3	
30.	Di.	18 .3	5 .9	
31.	Te.	19 .3	5 .3	
Aug. 2.	Rh.	5 .7	7 .7	
	Di.	12 .0	6 .0	
	Te.	16 .6	5 .3	
4.	Te.	13 .9	5 .4	
5.	Di.	5 .7	6 .0	
6.	Te.	11 .2	5 .4	
	Rh.	18 .1	7 .8	
7.	Di.	23 .4	6 .1	
8.	Te.	8 .5	5 .4	
1908.		**Gr. M. T.**	**y**	
Au. 10.	Te.	$5^h.8$	$5''.4$	North
	Di.	17 .1	6 .1	
11.	Rh.	6 .6	8 .0	
12.	Te.	3 .1	5 .5	
13.	Di.	10 .8	6 .2	
14.	Te.	0 .4	5 .5	
15.	Rh.	19 .0	8 .1	
	Te.	21 .7	5 .5	
16.	Di.	4 .5	6 .2	
17.	Te.	19 .0	5 .5	
18.	Di.	22 .2	6 .3	
19.	Te.	16 .3	5 .6	
20.	Rh.	7 .4	8 .2	
21.	Te.	13 .7	5 .6	
	Di.	15 .9	6 .3	
23.	Te.	11 .0	5 .6	
24.	Di.	9 .6	6 .4	
	Rh.	19 .9	8 .3	
25.	Te.	8 .3	5 .6	
27.	Di.	3 .3	6 .4	
	Te.	5 .6	5 .7	
29.	Te.	2 .9	5 .7	
	Rh.	8 .3	8 .4	
	Di.	21 .0	6 .5	
31.	Te.	0 .2	5 .7	
Sept. 1.	Di.	14 .6	6 .5	
	Te.	21 .5	5 .7	
2.	Rh.	20 .8	8 .6	?
3.	Te.	18 .8	5 .8	
4.	Di.	8 .4	6 .6	
5.	Te.	16 .1	5 .8	
7.	Di.	2 .0	6 .6	
	Rh.	9 .2	8 .7	?
	Te.	13 .4	5 .8	
9.	Te.	10 .8	5 .8	
	Di.	19 .7	6 .6	
11.	Te.	8 .1	5 .9	
	Rh.	21 .7	8 .8	?
12.	Di.	13 .4	6 .7	
13.	Te.	5 .4	5 .9	
15.	Te.	2 .7	5 .9	
	Di.	7 .1	6 .7	
17.	Te.	0 .0	5 .9	
18.	Di.	0 .8	6 .7	

1908.		Gr. M. T.	y	
Sep. 18.	Te.	21h.3	5″.9	North
20.	Di.	18 .5	6 .8	
	Te.	18 .6	5 .9	
22.	Te.	15 .9	5 .9	
23.	Di.	12 .2	6 .8	
24.	Te.	13 .2	5 .9	
26.	Di.	5 .9	6 .8	
	Te.	10 .5	6 .0	
28.	Te.	7 .8	6 .0	
	Di.	23 .6	6 .9	
30.	Te.	5 .2	6 .0	
Oct. 1.	Di.	17 .3	6 .9	
2.	Te.	2 .5	6 .0	
3.	Te.	23 .8	6 .0	
4.	Di.	11 .0	6 .9	
5.	Te.	21 .1	6 .0	
7.	Di.	4 .7	6 .9	
	Te.	18 .4	6 .0	
9.	Te.	15 .7	6 .0	
	Di.	22 .4	7 .0	
11.	Te.	13 .0	6 .0	
12.	Di.	16 .1	7 .0	
13.	Te.	10 .3	6 .1	
15.	Te.	7 .6	6 .1	
	Di.	9 .8	7 .0	
17.	Te.	5 .0	6 .1	
18.	Di.	3 .5	7 .0	
19.	Te.	2 .3	6 .1	
20.	Di.	21 .2	7 .1	
	Te.	23 .6	6 .1	
22.	Te.	20 .9	6 .1	
23.	Di.	14 .9	7 .1	
24.	Te.	18 .2	6 .1	
26.	Di.	8 .6	7 .1	
	Te.	15 .5	6 .2	
28.	Te.	12 .8	6 .2	
29.	Di.	2 .3	7 .1	
30.	Te.	10 .2	6 .2	
31.	Di.	20 .0	7 .1	
Nov. 1.	Te.	7 .5	6 .2	
3.	Te.	4 .8	6 .2	
	Di.	13 .7	7 .1	
5.	Te.	2 .1	6 .2	
6.	Di.	7 .4	7 .2	
	Te.	23 .4	6 .2	
8.	Te.	20 .7	6 .2	
9.	Di.	1 .1	7 .2	

1908.		Gr. M. T.	y	
No. 10.	Te.	18h.0	6″.2	North
11.	Di.	18 .8	7 .2	
12.	Te.	15 .4	6 .3	
14.	Di.	12 .5	7 .2	
	Te.	12 .7	6 .3	
16.	Te.	10 .0	6 .3	
17.	Di.	6 .2	7 .2	
18.	Te.	7 .3	6 .3	
19.	Di.	23 .9	7 .3	
20.	Te.	4 .6	6 .3	
22.	Te.	1 .9	6 .3	
	Di.	17 .6	7 .3	
23.	Te.	23 .3	6 .3	
25.	Di.	11 .3	7 .3	
	Te.	20 .6	6 .4	
27.	Te.	17 .9	6 .4	
28.	Di.	5 .0	7 .3	
29.	Te.	15 .2	6 .4	
30.	Di.	22 .7	7 .3	
Dec. 1.	Te.	12 .5	6 .4	
3.	Te.	9 .8	6 .4	
	Di.	16 .4	7 .3	
5.	Te.	7 .2	6 .4	
6.	Di.	10 .1	7 .3	
7.	Te.	4 .5	6 .4	
9.	Te.	1 .8	6 .4	
	Di.	3 .8	7 .3	
10.	Te.	23 .1	6 .4	
11.	Di.	21 .5	7 .3	
12.	Te.	20 .4	6 .4	
14.	Di.	15 .2	7 .4	
	Te.	17 .8	6 .4	
16.	Te.	15 .1	6 .4	
17.	Di.	8 .9	7 .4	
18.	Te.	12 .4	6 .4	
20.	Di.	2 .6	7 .4	
	Te.	9 .7	6 .4	
22.	Te.	7 .0	6 .4	
	Di.	20 .4	7 .4	
24.	Te.	4 .4	6 .4	
25.	Di.	14 .1	7 .4	
26.	Te.	1 .7	6 .4	
27.	Te.	23 .0	6 .4	
28.	Di.	7 .8	7 .4	
29.	Te.	20 .3	6 .4	
31.	Di.	1 .5	7 .4	
	Te.	17 .6	6 .4	

1909.		Gr. M. T.	y	1909.		Gr. M. T.	y
Jan. 2.	Te.	15h.0	6″.4 North	Jan 16.	Di.	11h.8	7″.5 North
	Di.	19 .2	7 .4	17.	Te.	17 .5	6 .4
4.	Te.	12 .3	6 .4	19.	Di.	5 .5	7 .5
5.	Di.	12 .9	7 .4		Te.	14 .8	6 .4
6.	Te.	9 .6	6 .4	21.	Te.	12 .2	6 .5
8.	Di.	6 .6	7 .4		Di.	23 .2	7 .5
	Te.	6 .9	6 .4	23.	Te.	9 .5	6 .5
10.	Te.	4 .2	6 .4	24.	Di.	16 .9	7 .5
11.	Di.	0 .3	7 .4	25.	Te.	6 .8	6 .5
12.	Te.	1 .6	6 .4	27.	Te.	4 .1	6 .5
13.	Di.	18 .0	7 .5		Di.	10 .6	7 .5
	Te.	22 .9	6 .4	29.	Te.	1 .4	6 .5
15.	Te.	20 .2	6 .4				

THE CORONAL SPECTRUM AS OBSERVED AT THE FLINT ISLAND ECLIPSE.

By W. W. Campbell and Sebastian Albrecht.

Two single-prism spectrographs were designed by Mr. Campbell for efficiency in recording the continuous spectrum of the corona. These and a three-prism spectrograph, referred to below, were mounted on one clock-driven polar axis. All were adjusted by Mr. Albrecht, assisted by Mr. Merfield, and the programme of observations at the time of the eclipse was carried out perfectly by Mr. Merfield. The slits of the three instruments extended east and west centrally across the Sun's image.

One of the single-prism instruments, using a Seed plate No. 27, was exposed from 0^m 5^s to 3^m 51^s. The spectrum of the extreme inner corona is recorded from λ 3550 to λ 5390. It is very strong for the first 2′ from the limb; the intensity falls off gradually out to a distance of 15′–20′ from each limb; and the intensity is then nearly uniform out to the ends of the slit, 49′ on the east side of the Sun and 40′ on the west. A continuous spectrum covers the region corresponding to the Moon, the intensities near the ends of the slit being slightly less than over the Moon.

A brilliant prominence on the east limb is the origin of a great number of overexposed bright lines. The following prominence lines are lengthened by the diffusion of the light in our atmosphere; their extent, measured from the east limb of the Moon being:—

$H\eta$	East 20′,	West 20′	
$H\zeta$	30	30	
K	49	72	Full length of slit, strong.
$H (+ H\epsilon)$	49	72	" " " " "
$H\delta$	49	33 +,	Ends in west coronal spectrum.
$H\gamma$	49	33 +,	" " " " "
λ 4471	30	30	Very faint.
$H\beta$	49	33 +,	Ends in west coronal spectrum.

A longer slit would no doubt have given still greater extent to the lines now limited at 49′ and 72′ The *H* and *K* calcium lines, especially, terminate abruptly at the points on the plate corresponding to the slit-ends.

The green bright line at λ 5303 and a bright line at λ 3601 3, the latter apparently new, are recorded in good strength, each out to 3′ from the west limb and 2′ from the east; the coronal line measured at λ 3987.0 is faintly visible, apparently lengthened by diffusion, on the strong continuous spectrum; the well-known coronal line measured at λ 4231.5 is easily visible, extending by diffusion entirely across the Moon and to the ends of the slit; a faint line at λ 3625.5, showing on both sides of the Sun, is short, but apparently a new coronal line; a faint line, visible on both sides, at λ 3643.3, and a more difficult line, showing only on the east side, at λ 3801.0, are probably coronal lines that have been observed before; a line 2′ long, showing only on the east side, at λ 3641 3, is of doubtful reality, and all other coronal bright lines appear to be lost in the strong continuous spectrum, the dispersion being low. The spectrum of the inner corona seems to be free from absorption-lines, at least out to 8′ or 10′ from the limb. The absorption-lines show very faintly in the spectrum of the outer corona, and still more faintly (and doubtfully) in the Moon's area, especially in the region λ 3900–4500. They are most readily observed in the regions lying between 10′ and 20′ from the limb. The maximum intensity of continuous

spectrum, estimated to lie at λ 4675, seems perceptibly further to the red than the maximum on the solar spectrograms obtained with the same instrument at Mt Hamilton,—signifying a lower effective temperature in the corona than in the Sun.

Cramer isochromatic instantaneous plates were used with the other single-prism instrument. One exposure, from $0^m\ 3^s$ to $0^m\ 20^s$, recorded nothing, no doubt on account of the clouds then prevailing. Another exposure, from $0^m\ 30^s$ to $3^m\ 51^s$, recorded the coronal spectrum very strongly. The spectrum for the inner corona extends from λ 3600 to λ 6000, all in good focus. The above description of the coronal spectrogram on the Seed plate applies in general to this spectrogram, taking its isochromatic character into account. The slit extended 47′ east of the Sun's image and 35′ west. The hydrogen and calcium lines of the prominence are likewise lengthened by diffusion, the *H* and *K* lines of calcium extending the full length of the slit,—47′ east and 68′ west from the prominence; the merest trace of an absorption spectrum is visible likewise in the mid-coronal region, and only in the violet. The intensities in the regions near the ends of the slit are clearly less than over the Moon.

The green coronal line, measured at λ 5301.4 ± 0.5, is strongly recorded, certainly to 20′ on the west and 15′ on the east. However, as this line is easily visible across the Moon's area, the great lengths are doubtless due in large measure to diffusion in our atmosphere. The bright coronal line at λ 4231.2 ± 0.2 is also recorded as of great length, especially on the west side. λ 3986.9 ± 0.2 is long but very difficult. A number of other coronal lines are suspected, but the strong background of continuous spectrum renders their existence uncertain. The dispersion being low, the wave-lengths assigned above are subject to slight error.

The interpretation of these spectrograms is a difficult matter, as the subject is more complex than it at first seems. There can be little doubt that the coronal spectrum combines three types: bright line, continuous, and dark-line. It further seems clear that *each point of the slit* receives light, by diffusion, from every prominence, from every point in the uneclipsed chromosphere, and from every point in the corona.

If the *H* and *K* calcium light is diffused in our atmosphere to cover the slit strongly to a distance of at least 72′ from the east limb, the apparent center of the effective diffusion, the brilliant light of the entire inner corona must by similar diffusion fall upon the entire length of the slit. We believe that this diffused inner-coronal light is chiefly responsible for the spectrum corresponding to the ends of the slit, and to that part of the slit covered by the Moon's image, and that ordinary sunlight diffused in the air in front of the instrument, from the illuminated atmosphere outside of the Moon's shadow, has contributed very little to the recorded spectrum. Thus the spectrum covering the Moon's section, neglecting diffused prominence and chromospheric radiations, is almost wholly a coronal spectrum. If it were in good part due to photospheric light, the absorption spectrum would be conspicuous; and the same could be said for those areas of the spectrogram corresponding to the ends of the slit. In fact, the true spectrum of the outer corona, say beyond 20′ from the limb, is either not recorded at all, or is masked by the superposed spectrum due to diffused light from the brilliant inner corona. It was remarked by the observers with previous experience—Messrs. PERRINE, ABBOT, and CAMPBELL—that the outer corona, as viewed by the naked eye, was disappointingly faint.

The proportion of light radiated by coronal particles appears to have been relatively large, and the sunlight diffused by the coronal particles relatively small, on this occasion. It appears that only in the region of the plates corresponding to the middle corona are the proportions of radiation spectrum, absorption spectrum (sunlight), and diffused inner-coronal spectrum such as to let the faintest traces of absorption-lines be detected. We do not feel that these facts militate against the theory of the corona held for several years by the Lick eclipse observers. Whether the stronger absorption spectra observed in Sumatra in 1901 and in Spain in 1905 indicate a variable coronal spectrum or the influence of the thin clouds over the corona in 1901 and 1905, is a question for future consideration.

A spectrograph of high dispersion, containing three extremely dense glass prisms, was used in the hope of recording the green coronal line, in order to determine its wave-length

with great accuracy. The solar spectrum was impressed upon the plate immediately after the end of the total eclipse, for reference. No trace of the coronal line exists on the plate, undoubtedly because of the strong absorption of the prisms.

TABLES OF THE ELEMENTS OF COMET-ORBITS, JANUARY, 1896, TO DECEMBER, 1907.

By J. C. Duncan.

The following tables have been prepared at the suggestion of Director Campbell, to supplement those compiled by W. C. Winlock, and published in *Publications* of the A. S. P., Vol. VIII, p. 141. Professor Winlock's tables include all the comets whose orbits were known and which reached perihelion before January 1, 1896; the tables here presented complete the list up to the present time.

The data were derived from the various astronomical periodicals, chiefly from the *Astronomische Nachrichten* and the *Astronomical Journal*. In each case that set of elements was chosen which most nearly represented the path of the comet.

Table I gives the elements of comets in order of perihelion passage. The numbers in the first column are continued from those of Winlock, which are identical with the numbers in Dr. Galle's catalogue of comet-orbits. The second column contains the designation of the comet according to the order of its discovery; in the case of well-known periodic comets this is followed by an abbreviation of the name of the comet's discoverer. These abbreviations are as follows:—

d'A = d'Arrest	Ho = Holmes
Bk = Brooks	T_2 = Tempel (second comet)
E = Encke	Tu = Tuttle
F = Fayé	W = Winnecke
Fi = Finlay	Wo = Wolf

The third and following columns give the orbital elements, as follows:—

T = time of perihelion passage, expressed in Greenwich mean time.

ω = the argument of perihelion, or the "longitude" of perihelion minus the longitude of ascending node.

Ω = longitude of ascending node.

i = inclination of orbit to ecliptic (when $i > 90°$ the motion is retrograde).

q = perihelion distance, in astronomical units.

a = semi-major axis of the orbit, in astronomical units.

U = period of revolution about the Sun, in years.

e = eccentricity of the orbit.

The eleventh column gives the names of the discoverers of new comets, and the last column contains remarks pertaining to the comets or their orbits.

In order to facilitate the comparison of the orbits of newly discovered comets with those already known, the comets given in Table I are rearranged in Tables II to V, in the order of magnitude of their various elements. Each comet is there indicated by the number applied to it in Table I, or, in the case of the periodic comets, by the abbreviation of the discoverer's name.

In these *Publications*, Vol. XIV, p. 49, Professor HUSSEY extended WINLOCK's Table I to January, 1902; but as he did not extend the other tables, the elements of those comets are reprinted here. HUSSEY's values of the elements do not differ materially from mine.

Since this list contains few periodic comets not given in WINLOCK's list, no classification was made in the order of a, U, or e.

Table I—Comets Arranged in Order of *T*.

No.	Designation.	*T*		ω	☊	*i*	*q*	*a*	*U*	*e*	Discoverer.	Remarks.
420	*a* 1896	1896, Jan.	31.8	358.5	208.9	155.8	0.588		*y*		Perrine.	
421	*b* 95 F	1896, Mar.	19.3	201.2	209.8	11.3	1.738	3.854	7.57	0.549		
422	*b* 96	1896, Apr.	17.6	1.7	178.3	55.6	0.566				Swift.	
423	*c* 96	1896, July	10.9	41.0	151.0	88.4	1.142				Sperra.	
424	*d* 96	1896, Oct.	26.0	139.5	192.1	11.6	1.482	4.325	9.00	0.657	Giacobini.	
425	*c* 1896 Bk	1896, Nov.	4.2	343.8	18.0	6.1	1.959	3.68	7.07	0.470		1889 V.
426	*g* 96	1896, Nov.	24.6	163.9	246.6	13.6	1.110	3.44	6.67	0.677	Perrine.	
427	*f* 96	1897, Feb.	8.1	172.4	86.3	146.1	1.062				Perrine.	
428	*a* 97 d'A	1897, May	23.9	173.1	146.4	15.7	1.321	3.55	6.69	0.627		
429	*b* 97	1897, Dec.	8.6	65.8	32.0	69.6	1.357				Perrine.	
430	*b* 1898	1898, Mar.	17.4	145.1	262.5	72.4	1.098				Perrine.	
431	*a* 98 W	1898, Mar.	20.4	173.4	100.9	17.0	0.924	3.240	5.82	0.415		
432	*d* 98 E	1898, May	27.8	184.0	334.8	12.9	0.341	2.22	3.285	0.846		
433	*f* 98 Wo	1898, July	4.6	172.9	206.4	25.2	1.604	3.597	6.82	0.555		
434	*g* 98	1898, July	25.5	22.4	278.3	166.8	1.501				Giacobini.	
435	*c* 1898	1898, Aug.	16.2	205.6	259.1	70.0	0.626				Perrine.	
436	*c* 98	1898, Sept.	14.0	233.3	74.0	69.9	1.702				Coddington.	
437	*j* 98	1898, Sept.	20.2	4.6	95.8	22.5	2.269				Chase.	
438	*h* 98	1898, Oct.	20.5	162.4	34.9	28.8	0.420				Perrine.	
439	*i* 98	1898, Nov.	23.2	123.6	96.3	140.4	0.756				Brooks.	
440	*a* 1899	1899, Apr.	13.0	8.7	25.0	146.2	0.327			1.0004	Swift.	Hyperbolic.
441	*d* 99 Ho	1899, Apr.	28.1	14.1	331.7	20.8	2.129	3.615	6.88	0.411		
442	*b* 99 Tu	1899, May	14.1	206.8	269.7	54.3	1.024	5.74	13.76	0.822		
443	*c* 99 T_2	1899, July	28.5	185.1	121.2	12.7	1.351	3.008	5.218	0.551		
444	*e* 99	1899, Sept.	15.0	10.9	272.2	76.9	1.786				Giacobini.	
445	*a* 1900	1900, Apr.	28.2	23.1	40.1	146.6	1.346				Giacobini.	
446	*b* 00	1900, Aug.	3.2	12.4	328.0	62.5	1.015				Borrelly-Brooks.	
447	*c* 00	1900, Dec.	1.4	175.9	192.6	31.0	0.977				Giacobini.	
448	*a* 01	1901, Apr.	24.3	203.0	109.8	131.0	0.244				Holk.	Quite bright.
449	*b* 01 E	1901, Sept.	15.4	184.0	334.8	12.9	0.341	2.22	3.285	0.846		

450	*a* 1902	1902, May	7.2	228.4	52.2	66.5	0.451				Brooks.	
451	*c* 02	1902, June	20.	292.7	217.8	18.4	0.530				Grigg.	{Observed by Grigg only. Orbit very uncertain.
452	*b* 02	1902, Nov.	23.9	152.9	49.3	156.3	0.401				Perrine.	Bright.
453	*a* 03	1903, Mar.	16.0	133.7	2.3	30.9	0.411				Giacobini.	
454	*d* 02	1903, Mar.	23.9	6.0	117.5	43.9	2.770				Giacobini.	
455	*b* 1903	1903, Mar.	25.4	185.0	213.1	66.5	0.499				Grigg.	
456	*c* 03	1903, Aug.	27.6	127.4	293.5	85.0	0.329				Borrelly.	Quite bright.
457	*d* 03 Bk	1903, Dec.	11.	343.8	18.1	6.1	1.959	3.68	7.07	0.470		1889 V.
458	*a* 04	1904, Mar.	7.1	53.5	275.8	125.1	2.707				Brooks.	
459	*d* 04	1904, Nov.	4.2	41.3	218.5	99.7	1.885				Giacobini.	
460	*c* 1904 T_2	1904, Nov.	10.3	185.7	121.0	12.6	1.201	2.622	5.282	0.542		
461	*b* 04 E	1905, Jan.	11.6	184.0	334.8	12.9	0.341	2.22	3.285	0.846		
462	*e* 04	1905, Jan.	16.5	352.2	76.6	30.6	1.399	3.730	7.30	0.628	Borrelly.	
463	*a* 05	1905, Apr.	4.1	358.2	157.5	40.2	1.114	42.69	200.62	0.967	Giacobini.	
464	*b* 06	1905, Oct.	20.8	159.1	342.2	4.2	3.316				Kopff.	Orbit indeterminate.
465	*b* 1905	1905, Oct.	25.7	132.7	222.9	140.6	1.052				Schaer.	
466	*a* 06	1905, Dec.	22.2	89.7	286.4	126.5	1.295				Brooks.	
467	*c* 05	1906, Jan.	22.4	199.3	92.1	43.7	0.215				Giacobini.	Bright.
468	*c* 06	1906, Feb.	21.5	278.7	72.8	81.4	0.743				Ross.	Few observations.
469	*f* 06 Ho	1906, Mar.	14.2	14.3	331.8	20.8	2.122	3.609	6.88	0.412		
470	*e* 1906	1906, May	2.1	19.5	263.8	8.7	1.699	3.542	6.667	0.520	Kopff.	
471	*d* 06 Fi	1906, Sept.	7.3	315.8	52.4	3.1	0.998	3.540	6.532	0.724		
472	*h* 06	1906, Oct.	16.4	205.1	193.2	14.1	1.630	3.622	6.894	0.550	Metcalf.	
473	*g* 06	1906, Nov.	21.1	8.6	84.9	56.5	1.215				Thiele.	
474	*a* 07	1907, Mar.	19.2	317.2	97.2	141.7	2.052				Giacobini.	
475	*b* 1907	1907, Mar.	27.6	328.8	189.1	110.2	0.924				Mellish-Grigg.	Preliminary elements.
476	*c* 07	1907, May	31.2	39.6	160.9	14.8	1.237				Giacobini.	
477	*d* 07	1907, Sept.	4.0	294.4	143.0	9.0	0.512				Daniel.	Very bright.
478	*e* 07	1907, Sept.	14.5	294.5	54.6	119.7	0.984				Mellish.	

Table II—Comets Arranged in Order of ω.

ω		Numbers.	ω		Numbers.
0° to	10°	422, 437, 454, 473, 440	180° to	190°	E, T_2, 455
10	20	444, 446, Ho, 470	190	200	467
20	30	434, 445	200	210	F, 448, 472, 435, Tu
30	40	476	210	220	
40	50	423, 459	220	230	450
50	60	458	230	240	436
60	70	429	240	250	
70	80		250	260	
80	90	466	260	270	
90	100		270	280	468
100	110		280	290	
110	120		290	300	451, 477, 478
120	130	439, 456	300	310	
130	140	465, 453, 424	310	320	Fi, 472, 474
140	150	430	320	330	475
150	160	452, 464	330	340	
160	170	438, 426	340	350	Bk
170 to	180	427, Wo, d'A, W, 447	350 to	360	462, 463, 420

Table III—Comets Arranged in Order of ☊.

☊		Numbers.	☊		Numbers.
0° to	10°	453	180° to	190°	475
10	20	Bk	190	200	424, 447, 472
20	30	440	200	210	420, F, Wo
30	40	429, 438	210	220	451, 455, 459
40	50	445, 452	220	230	465
50	60	450, Fi, 478	230	240	
60	70		240	250	426
70	80	468, 436, 462	250	260	435
80	90	473, 427	260	270	Tu, 430, 470
90	100	437, 439, 467, 474	270	280	434, 444, 458
100	110	W, 448	280	290	466
110	120	454	290	300	456
120	130	T_2	300	310	
130	140		310	320	
140	150	477, d'A	320	330	446
150	160	423, 463	330	340	432, Ho, E
160	170	476	340	350	464
170 to	180	422	350 to	360	

TABLE IV—COMETS ARRANGED IN ORDER OF i.

i		Numbers.	i		Numbers.
0° to	10°	Bk, 464, 470, Fi, 477	90° to	100°	459
10	20	F, 424, 426, d'A, W,	100	110	
		E, T_2, 451, 472, 476	110	120	475, 478
20	30	Wo, 437, 438, Ho	120	130	458, 466
30	40	447, 453, 462	130	140	448
40	50	454, 463, 467	140	150	427, 439, 440, 445,
50	60	422, Tu, 473			465, 474
60	70	429, 436, 446, 450, 455	150	160	420, 452
70	80	430, 435, 444	160	170	434
80 to	90	423, 456, 468	170	to 180	

TABLE V—COMETS ARRANGED IN ORDER OF q.

q		Numbers.	q		Numbers.
0.0 to	0.2		1.4 to	1.6	424, 434
0.2	0.4	E, 440, 448, 456, 467	1.6	1.8	F, Wo, 436, 444, 470,
0.4	0.6	420, 422, 438, 450, 451,			472
		452, 453, 455, 477	1.8	2.0	Bk, 459
0.6	0.8	435, 439, 468	2.0	2.5	437, Ho, 474
0.8	1.0	W, 447, Fi, 475, 478	2.5	3.0	454, 458
1.0	1.1	427, 430, Tu, 446, 465	3.0	4.0	464
1.1	1.2	423, 426, 463	> 4.0		
1.2	1.3	T_2, 466, 473, 476			
1.3 to	1.4	d'A, 429, T_2, 445, 462			

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1908.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter..July 6, $12^h\ 25^m$ P.M.	First Quarter..Aug. 5, $1^h\ 40^m$ A.M.
Full Moon...... " 13, 1 48 P.M.	Full Moon...... " 11, 8 59 P.M.
Last Quarter... " 20, 4 2 A.M.	Last Quarter... " 18, 1 25 P.M.
New Moon..... " 27, 11 17 P.M.	New Moon..... " 26, 2 59 P.M.

The Earth reaches its greatest distance from the Sun on July 2d at about 11^h A.M., Pacific time.

Mercury is not in good position for naked-eye observation during July and August. It is an evening star on July 1st, but is very close to the Sun, and passes inferior conjunction on July 4th, becoming a morning star. It then moves away from the Sun toward greatest west elongation, reaching that point on July 25th. The planet's apparent distance from the Sun is then 19° 51′,—a much smaller greatest elongation than the average because it occurs less than four days after perihelion. It then rises a little less than an hour and one half before sunrise, and may be seen in the morning twilight for a few days. It then moves out toward superior conjunction, reaching it on August 20th, and becoming an evening star, but does not reach a sufficient distance from the Sun to be seen in the evening twilight before the close of the month. *Mercury* is in conjunction with *Venus* on July 15th, with *Neptune* on July 28th, with *Jupiter* on August 18th, and with *Mars* on August 20th, but none of these conjunctions can be observed with the naked eye on account of the proximity of the planets to the Sun.

Venus on July 1st is, like *Mercury*, an evening star, very close to the Sun, reaching conjunction and becoming a morning star on July 5th. The distance between Sun and planet increases very rapidly, so that by August 1st *Venus* rises considerably more than two hours before sunrise, and by the end of the month the interval is a little more than three and

a half hours The planet will reach its greatest west elongation before the middle of September. The planet will again be very bright in late July and early August, reaching the maximum on August 11th. As in the previous May, it will then be bright enough to be seen by the naked eye in full sunlight. It is not easy to find, but when once seen in daylight it seems so conspicuous that one wonders at the difficulty in finding it. It is easiest picked up when the sky is clear but partially covered with drifting clouds. One can keep his eye on a rift in the cloud as it gradually passes over the place where the planet is known to be, and thus find the planet more easily than he can when there is no cloud.

Mars is too near the Sun throughout July and August to be easily seen. It is still an evening star on July 1st, and then sets only about an hour after sunset As the planet by this time has gradually faded away to about the brightness of the pole-star, it will not be an easy matter to see it in the evening twilight. The distance between *Mars* and the Sun gradually diminishes until conjunction is reached, on the night of August 21st, and the planet becomes a morning star. The distance between Sun and planet then increases, but does not become great enough to permit the planet's being seen in the morning twilight until some time after the end of the month. At the time of conjunction with the Sun the distance of *Mars* from the Earth is 248,000,000 miles. This is more than 10,000,000 miles greater than it is at an average conjunction, since both the Earth and *Mars* are at nearly their maximum distance from the Sun, the Earth having passed aphelion on July 2d, while *Mars* will be in aphelion on September 3d At the last opposition, in July, 1907, *Mars* was near perihelion while the Earth was in aphelion, but both were then on the same side of the Sun, and they were much nearer together than at an average opposition. The same thing will occur at the next opposition, late in the summer of 1909.

Jupiter sets at about 9^h 30^m P M. on July 1st, about two hours after sunset, and may be easily seen in the evening twilight, but its apparent distance from the Sun is lessening rapidly, so that by the end of the month it is only about 12° distant and it sets only forty minutes after sunset. As it is one of the brightest of the planets it may possibly be seen close to the

horizon about half an hour after sunset, but only under the best of atmospheric conditions. Conjunction with the Sun occurs on August 17th, and the planet becomes a morning star. By the end of the month it has moved far enough away from the Sun so that the conditions of visibility are a little better than they were at the beginning of the month.

Saturn rises at about midnight on July 1st, and at about 8^h P.M. on August 31st. It is in the constellation *Pisces,* and moves slowly eastward until July 23d, and then begins to move westward; but the whole motion is only about 1°, an amount hardly noticeable, as there are no bright stars nearby so that small changes in position can be marked. As seen in the telescope, the rings appear about as they did during June, but the Earth in its annual motion begins to draw nearer the plane of the rings during August, and there will be slight narrowing, which will continue until December.

Uranus comes to opposition with the Sun on July 7th, and will then be above the horizon throughout the entire night. By the end of August it sets at a little before 1^h A.M. During the two months' period it moves about 2° westward in the constellation *Sagittarius,* and is about 5° north of the most eastern star in the bowl of the "milk-dipper," not far from a line between that star and π *Sagittarii,* and nearer the latter.

Neptune comes to conjunction with the Sun and becomes a morning star on July 6th. It remains in the constellation *Gemini.*

NOTES FROM PACIFIC COAST OBSERVATORIES.

Recent Double-Star Literature.

The most important of the recent publications relating to double-star astronomy is the "Catalogue and Remeasurement of the 648 Double Stars Discovered by Professor G. W. Hough," issued as Volume III, Part III, of the Astronomical Series of the Publications of the University of Pennsylvania. The author is Professor Eric Doolittle, who has in this volume done for the Hough stars what Burnham, Hussey, and Lewis had previously done for the Burnham, Otto Struve, and Struve stars, respectively.

Professor Doolittle's plan involved a complete remeasurement of all the stars discovered by Hough. This was begun in 1901, and practically completed within the next two years. The Hough stars, however, include a number that are very close pairs, and hence exceedingly difficult to measure with an 18-inch telescope. There are also sixteen pairs that have never been seen double since Hough listed them. The stars in these two classes, especially the latter, required careful watching for a number of years before satisfactory measures could be secured or the definite statement made that the star was single at the present time.

The work as it now appears is very satisfactory from every point of view. The measures have been made in the careful and thorough manner that has characterized all of Doolittle's work, and the arrangement of the results is convenient, and enables the reader to gather quickly all extant information regarding any star.

In his Introduction, Professor Doolittle comments on the comparatively few measures that have hitherto been made of the Hough stars. Only twenty-three of them have been measured more than five times, 494 have been measured by Hough only, and sixty-six of these on only one night. It was thus

obvious that systematic remeasurement was urgently demanded. As might have been expected, however, the new measures have revealed orbital motion in comparatively few pairs. This is mainly due to the fact that none of HOUGH's discoveries date back thirty years, his first list, containing 209 pairs discovered between 1881 and 1886, having been published in 1887; and some are more recent than 1898. That a large percentage will ultimately show orbital motion cannot be doubted, for nearly four hundred of the Hough pairs have distances under 5″, and the probability that such pairs are binary systems is so great as to amount to practical certainty. It will take a long time, however, for the orbital motion to become evident, and careful examination of the volume before us indicates that it will be unnecessary to remeasure the greater number of Hough stars for another quarter of a century. About 100 pairs, on the other hand, ought to be remeasured within the next few years, and fully half that number should be closely watched.

The most interesting star in the catalogue is 13 *Ceti* = Ho 212, on the rapid motion of which the present writer has commented in earlier numbers of these *Publications*.[1] Professor DOOLITTLE has computed the orbit of this pair with results that are in satisfactory agreement with my own, the two revolution periods being 7.42 and 7.35 years.

Among other publications of interest to double star observers we note the new series of articles on "Double-Star Astronomy" now appearing in *The Observatory*. In 1893 Mr. THOMAS LEWIS, of the Greenwich Observatory, published a series of papers with the same title in the same journal. The present series, which began in the February (1908) number, is a second edition, revised and brought up to date. The general reader as well as the specialist will find much to interest him in these articles.

In the *Astronomische Nachrichten*, No. 4229, Dr. W. A. DOBERCK publishes a paper entitled "On the Accuracy of Measures Made by the Principal Double-Star Observers," in which he gives the results of comparisons of observations with positions computed from the orbits of thirty binaries which he has lately investigated. The paper is a very interesting one, and brings out clearly several important points. The first is that the probable errors of measurement are in general very small,

[1] See Vol. XVII, pp. 26 and 150; Vol. XIX, p. 54.

seldom exceeding 0″.05 in either angle or distance. In the second place, it is evident that the size of the error is influenced by the relative magnitudes of the two components, and also by their angular separation. The interesting point is developed that the probable error of angle measure, as well as of distance measure, in general *increases* with increasing distance, within the limits investigated.

In another number of the same journal (4235), Dr. DOBERCK continues his study of binary stars with an orbit of γ *Virginis*. It may be added that Dr. DOBERCK has recently established a private observatory near London, in England, and has resumed the active observation of double stars in addition to his mathematical researches.

Rev. T. E. ESPIN continues his work on double stars with unabated enthusiasm, as is evident from his "Fifth Series of Measures of Double Stars" and "A List of 109 New Double Stars," which are published in the *Monthly Notices* R. A. S. for January, 1908. Of the new pairs five are under 2″ and the majority under 10″, though a number of wider pairs are included. The desirability of listing the wider pairs as double stars seems questionable to the present writer. The only object it can have is to call attention to these pairs in the hope that they will be measured, and whatever relative motion may exist be thus brought to light. But experience has demonstrated that relative motion is very slow, even in the moderately close pairs—those from 2″ to 5″. Would it not be wiser to concentrate the energies of micrometer observers upon these and *closer* pairs, leaving the motion in the wider pairs to be discovered by photographic methods?

The same number of *Monthly Notices* contains orbits of the binaries β 80, β 513, and β 552, by Dr. T. J. J. SEE. These are all of interest, and will serve to call new attention to systems that ought to be measured every year or two. The observations of the next ten or fifteen years should furnish data to improve these first approximations to the elements.

Double-star observations occasionally appear in unexpected places. Thus the "Katalog von 10663 Sternen," just published as No. 10 of the New Bonn Observatory Publications, by Professor F. KÜSTNER, gives, on pp. 79-94, a list of micrometric measures of double stars and companion stars within 1′

detected during the course of the meridian-circle observations. Only such pairs have been measured as had not been adequately measured elsewhere.

R. G. AITKEN.

May 22, 1908.

PROGRESS ON THE CROSSLEY *EROS* SOLAR PARALLAX WORK.

The work of determining the solar parallax from the photographs of *Eros*, taken with the Crossley reflector in 1900, is almost completed. The plates which were selected for use have all been measured and reduced by Mrs. MOORE (*née* CHASE) and Miss HOBE. For some months now a discussion and comparison of the results has been in progress. This discussion is nearly completed, and it is hoped soon to send the manuscript to the printer.

While the final parallax has not yet been derived, it can be said that it will hardly differ 0″.010 from 8″.800.

MT. HAMILTON, May 21, 1908.

C. D. PERRINE.

RECENT OBSERVATIONS OF THE MOVING OBJECT NEAR *JUPITER*, DISCOVERED AT GREENWICH BY MR. J. MELOTTE.

After the receipt of the telegraphic announcement of the discovery of this object, early in March, Dr. ALBRECHT obtained some photographs of the region with the Crossley reflector, on the nights of March 7th, 8th, and 9th. The new object (as well as the sixth and seventh satellites) is shown on the plates of March 8th and 9th. A position obtained on March 8th has been published.

Photographs have been obtained by the writer on March 24th, 27th, 31st, April 1st, 28th, and 29th, on which the Greenwich object, the sixth and seventh satellites are shown. The following positions have been derived from the photographs of April 1st and 29th:—

April, 1908.

1^d	8^h	51^m	0^s	P. S. T.	α 1908.0	8^h	26^m	$45^s.58$	δ 1908.0	$+19°$	$49'$	$27''.4$
29	8	51	15			8	33	44 .22		+19	35	49 .0

In brightness, the new object differs but little from the seventh satellite.

From a preliminary discussion of the observations from January 27th to April 3d, the Greenwich astronomers conclude that it belongs to *Jupiter*.[1]

[1] *The Observatory* for May, 1908, and *A. N.*, No. 4246.

Mr. MELOTTE is to be congratulated upon so important a discovery. It is all the more creditable because it comes in the line of regular, routine work in observing satellites photographically, of which a number of valuable contributions have been published from Greenwich. It is also a credit to a climate which has the reputation of being unsuited to the exactions of large telescopes. C. D. PERRINE.

MT. HAMILTON, May 21, 1908.

MEASURES OF β 208.

Dr. SEE has recently called attention to this binary star, stating that it is now passing periastron, and that the relative motion is therefore very rapid and the companion perhaps invisible. The following measures, made with the 36-inch refractor, may therefore be of interest:—

1907.21	181°.4	0″.35	2^n
1908.28	190 .0	0 .39	1^n

Comparing these positions with my measures in the two preceding years, viz:—

1905.18	167°.5	0″.30	2^n
1906.10	177 .3	0 .30	5^n

it does not appear that the apparent motion is increasing in rapidity at the present time. It would seem that any estimate of the form of the orbit is premature. R. G. AITKEN.

May 22, 1908.

EXPLANATION AND CORRECTION.

The two half-tone illustrations of the solar corona accompanying my article, "The Crocker Eclipse Expedition of 1908," in the last number of these *Publications,* made and printed by an Eastern firm, were excellent in the proof-sheets supplied us, but so poor in the printed product that we regret having made another attempt to publish a corona in this manner. The engraver's printer has been the means of sadly misrepresenting this section of the expedition's work. An error was made, also, in orienting the half-tone block of the smaller corona (Frontispiece): the side marked *IV* should have been marked *N,* etc. W. W. CAMPBELL.

REPORTS OF OBSERVATORIES.

LICK OBSERVATORY, MT. HAMILTON, CALIFORNIA.

The last number of these *Publications* contains a full account of the Crocker Eclipse Expedition dispatched to Flint Island to observe the total solar eclipse of January 3, 1908. It is therefore unnecessary, in this record of observatory activities in 1907, to refer to the subject, further than to say that the preparations at Mt Hamilton and on Flint Island, and travel to the island, occupied the time of Messrs. CAMPBELL, PERRINE, AITKEN, and ALBRECHT during the three or four closing months of the year. It is expected that the results of this very successful expedition will all be presented in these *Publications* from time to time, as ready, in 1908 Professor LEWIS, of the Department of Physics, University of California; Professor BOSS, in charge of the U. S. Naval Observatory, Pago Pago, Samoan Islands; Mr. MERFIELD, of the Sydney Observatory; and Consul and Mrs. DREHER, of Papeete, Island of Tahiti, were valued members of the expedition.

The observations with the meridian circle in charge of Astronomer TUCKER, aided by Carnegie Assistant R. F. SANFORD, were confined principally to the completion of two years' work on a programme for determining the accurate positions of stars based on fundamental methods About 1900 observations on this programme were secured during the year. The stars on the programme are distributed mainly between 37° north and 37° south declination. Special stars are included in the programme for the purpose of determining the observer's personal errors as affected by his position while making the observations, and by the direction of the apparent motion of the stars through the field of view. Other stars for the investigation of atmospheric refraction effects were selected from 60° to 65° north declination, and observed at upper and lower culminations. These will give observed effects down to more than 80° zenith distance in the north, and selected southern stars having similar zenith distances were observed for the same purpose. The reductions of the observations for the two years are well advanced.

Mr. TUCKER'S problem is complicated by the existence of a daily period in the azimuth of the instrument, as shown clearly by both the first and the second year's observations. The meridian mark (mire) appears to give consistent results for periods of considerable length, and the diurnal azimuth variations observed are clearly due to changes in the position of the instrument itself. It is only by making observations at all hours of the day that the azimuthal changes can be resolved into their component parts and the necessary corrections be applied to the observations.

During the year, Volume X, *Publications of the Lick Observatory*, containing Professor TUCKER'S observations with the meridian circle obtained in 1901-6, was published and distributed. The principal contents of the volume consist of a catalogue of 2798 zodiacal stars. The stars in the list were selected by Sir DAVID GILL as a basis for heliometer measures of the Moon and planets. The volume also contains observations of other special lists of stars, as well as a discussion of the graduation errors of the circles.

In the year 1907 a special list of stars was observed for Dr. L. DE BALL, of Vienna, for use in his determinations of stellar parallax. The right ascension of the Moon was observed on several nights in the fall and winter of 1907 to determine the effect of existing errors in the Moon's ephemeris position on the predicted times for the total solar eclipse of January 3, 1908. Mr. TUCKER found that the Moon was more than 0.4 of a second east of its published position This discrepancy would cause the eclipse to occur about twenty seconds of time earlier than predicted.

The optical system of the Crossley reflector consisted exclusively of the 36½-inch silver-on-glass mirror, which has a ratio of aperture to focal length of 1 : 5.8. This ratio is not suitable for the collimator of a spectrograph, and, likewise, the scale of stellar photographs is too small to admit of the very accurate observations required in parallax determinations. Quite extensive investigations by Dr. PERRINE and Dr. ALBRECHT established clearly the desirability of reducing the magnitudes of unavoidable errors by increasing the equivalent focal length To this end Mr. F. G. PEASE, expert optician to The Scientific Shop, in Chicago, spent four weeks on Mt.

Hamilton in the summer of 1907, figuring a 9¾-inch hyperboloidal mirror for the Crossley reflector, in order to convert the telescope into the Cassegrain form. A third mirror, with flat surface, is mounted diagonally with reference to the incident light, immediately in front of the parabolic mirror, in order to direct the beam through the side of the telescope-tube near its lower end. The equivalent focal length has been increased by the combination to about seventy feet. Professor PERRINE, who designed the necessary mechanical additions, and assisted Mr. PEASE in the tests, is hoping promptly to utilize the telescope, thus modified, in the development of stellar-parallax methods, and Mr. CAMPBELL is planning for spectrographic work on certain especially interesting types of stars in the near future.

The most extensive investigation under way is that of determining the radial velocities of the brighter stars by means of the Mills spectrograph attached to the 36-inch refractor, in accordance with a programme entered upon by Mr. CAMPBELL in 1896. This programme hopes to include all the stars whose photographic magnitudes are equal to or brighter than 6.0, lying north of — 25° declination, with the addition of essentially all of the stars brighter than the fifth magnitude between — 25° and — 30° declination. The number of stars on the list is approximately 750, but a certain number of these are not amenable to accurate observation, for the reason that their spectra do not contain sharply defined lines. The number of spectrograms secured with the 3-prism Mills instrument in 1907 was approximately 500. The total number of spectrograms obtained up to January 1, 1908, was 5,086. The number is not increasing so rapidly in recent years as formerly, because the greater part of our attention is now given to fainter stars requiring longer exposures. It is interesting to note that we have found it possible to use wider slits and, at the same time, obtain spectra of sufficient purity to permit accurate measurement. In this way we are able, under average conditions of seeing, to obtain good spectra of stars of 6.0 photographic magnitude in from two hours to two and a half hours.

Of the 500 plates exposed in 1907, practically all have been measured and reduced approximately, and fifty definitively. The observing in this programme was carried on by Messrs.

CAMPBELL, WRIGHT, MOORE, and ALBRECHT. Since November 1st, Mr. H. C. PLUMMER, Fellow, has also observed regularly. Occasional assistance was rendered by Carnegie Assistant K. BURNS, by Fellows J. C. DUNCAN and E. A. FATH, and by visiting astronomers Dr. C. A. CHANT and Dr. A. B. TURNER.

During the year eleven spectroscopic binaries were discovered in the course of the regular observing programme—one by Mr. CAMPBELL, one by Mr. PLUMMER, and nine by Mr. MOORE.

Dr. MOORE is making a new investigation of the orbit of the variable binary-star δ *Cephei*, forty-one 3-prism spectrograms having been secured in 1907 for this purpose.

Two hundred and fifty definitive measures of 3-prism spectrograms, made by Carnegie Assistant NEWKIRK up to the date of his departure in September, have been reduced by Miss LEAH ALLEN, Carnegie Assistant.

The measures and reductions of all spectra taken with the Mills spectrograph between August, 1907, and July, 1903, were completed by Carnegie Assistant BURNS in July, 1907, as the result of his three years' work. Mr. BURNS's extensive spectrographic investigation of the rotation of *Venus*, while not yielding positive evidence as to the rotation period of that planet, was valuable in making clear the elements of the problem and in indicating the desirable features of apparatus and methods for obtaining a satisfactory solution.

Spectrographic observations of *Polaris* obtained in the past two years show that the velocity of the bright component in the line of sight is slowly approaching that observed by Mr. CAMPBELL in 1896. The long period of this interesting triple star cannot now be defined, but it is probably between twelve and twenty-five years.

Dr. A. B. TURNER, of the College of the City of New York, completed his investigation of the orbit of the spectroscopic binary ω *Draconis*, which he carried on during the summer vacations of 1906 and 1907.

Dr. ALBRECHT's paper on "A Spectroscopic Study of the Fourth Class Variable Stars, *Y Ophiuchi* and *T Vulpeculæ*," completed in 1907, brought out the fact that, in the δ *Cephei* class of variables, a relation apparently exists which promises to be extremely significant in determining why these stars

vary. He found, in the ten stars of this class thus far investigated, that the maximum of brilliancy occurred at or very near the time when the bright component of each of these binary systems was moving toward the observer. No exception to this rule has been noted. Inasmuch as the ten observed stars are distributed through a considerable area of the sky, it is surprising to find that the time of greatest brightness is apparently dependent upon the observer's position in space. It may easily transpire that this is one of the most significant discoveries concerning variable stars made in recent years.

The work of the D. O. Mills Expedition to the southern hemisphere, interrupted in 1906 while numerous improvements in and additions to the apparatus were made, and more or less by the great earthquake of August, was prosecuted vigorously by Astronomer CURTIS and Assistant PADDOCK throughout the year 1907. A large number of stellar spectrograms were secured with the 3 prism, 2-prism, and 1-prism instruments. All of these were measured and reduced provisionally, and many of them definitively. The orbits of several interesting spectroscopic binary stars were investigated and published. The diurnal range of focal length, caused by rapid changes of temperature, formerly so troublesome, has been eliminated by Dr. CURTIS through the use of the refrigerating apparatus recently described in these *Publications*.

The measurement and reduction of the 800 spectrograms obtained during the original two-year period of observation by Professor WRIGHT and Assistant PALMER were completed on Mt. Hamilton about the middle of 1907 by Messrs WRIGHT and ALBRECHT. Both have made extensive studies of systems of normal wave-lengths to be used as a basis for applying the final corrections to the southern hemisphere results.

Dr ALBRECHT continued during the year, as time was available, his study of the effective wave-lengths of spectrum lines as dependent upon spectrum type.

Dr AITKEN has continued the double-star survey of the northern sky, according to the systematic plans described in former reports. During the year 1907 he examined about 8,500 stars, down to the 9.0 magnitude inclusive, with the 12-inch and 36-inch refractors, and 250 of these stars were found to be double, all the pairs having distances less than

five seconds. This number is smaller than that reported in 1906, partly because of unusually bad observing conditions in the first half of the year and partly because of absence on the eclipse expedition. These discoveries include a number of pairs likely to prove of more than ordinary interest. We may mention the very close and bright pairs κ *Ursæ Majoris* (4.5 magnitude) and ν^2 *Bootis* (5.0 magnitude). It is expected that this survey, as carried on at Mt. Hamilton, will extend to — 22° declination Fully eighty-five per cent of the survey has been completed, and, given ordinary observing conditions, this section of the work should be finished in the summer of 1910. Prior to January, 1908, more than 3,000 close doubles had been discovered, as one result of the survey—1,300 + by Professor HUSSEY and 1,700 by Professor AITKEN.

It is scarcely necessary to say that the great value of this notable survey lies not in these discoveries themselves, but in the enormously increased opportunity which the discoveries will afford in the future study of double stars in particular and of the structure of the sidereal universe in general. Holding the requirements of this study in mind, the systematic qualities of the search are rigidly maintained, and at least two satisfactory micrometer measures of each pair are secured, as promptly as practicable, before announcing the discovery. It is hoped, for example, that future computers of their orbits will have the great advantage of an accurate discovery-position in every case.

About one hundred of the more important and difficult of the well-known double stars are kept under observation, measures being made as often as they are needed to improve our knowledge of the orbital motion To refer to only one pair: Dr. AITKEN'S measures of the binary 13 *Ceti*, discovered by HOUGH in 1886, have enabled him to establish that the revolution period of this system is only 7.4 years; next to that of δ *Equulii*, the shortest period known.

Micrometer observations of the satellites of *Uranus* and of the inner satellites of *Saturn* were continued by Dr AITKEN with the 36-inch refractor. Eclipses of *Saturn's* satellites were observed on six nights, and close attention was given to the phenomena presented by *Saturn's* rings, whose plane passed through the Earth twice and through the Sun once during

the year. The causes of the curious bright knots, or condensations, observed in the rings, here and elsewhere, are undergoing discussion in several journals, and our knowledge of the structure of the rings promises to be increased.

Micrometer observations of comet positions have been obtained as follows:—

Comet	*a* 1907,	2 nights,	AITKEN
Comet	*a* 1907,	4 "	FATH
Comet	*b* 1907,	6 "	AITKEN
Comet	*c* 1907,	1 "	AITKEN
Comet	*d* 1907,	4 "	AITKEN
Comet	*d* 1907,	12 "	DUNCAN
Comet	IV 1905,	5 "	AITKEN
Comet	*e* 1907,	7 "	DUNCAN

Comet 1905 IV, discovered by KOPFF in March, 1906, and later found on photographic plates taken at Heidelberg in January, 1905, was under observation for a longer consecutive time than any previous comet.

Micrometer positions of asteroids have been obtained as below:—

Nemesis (128), 2 nights, AITKEN.

Mr. FATH, Fellow, began an extensive study of the zodiacal light, with special reference to polarization effects and the character of its spectrum. One spectrogram exposed by Mr. FATH on several successive nights, and another exposed for Mr. FATH's use by Mr. DUNCAN, recorded the spectrum in good strength. The study will be renewed on Mr. FATH's return in the summer of 1908. Interpretation of the observations will be deferred until more data are available.

Observations of *Jupiter's* satellites VI and VII, with the Crossley reflector, were secured by Messrs. PERRINE and ALBRECHT.

The application of electric power to moving the Crossley dome and to winding the clock, in combination with the splendid clock-driving, has rendered unnecessary the services of an assistant to the Crossley observer.

Good progress was made in the preparation of heliogravure plates of Professor KEELER's nebular photographs, with reference to their publication in volume form. To secure satisfac-

tory reproductions by mechanical processes has been a long struggle, so great are the difficulties encountered; but it is confidently expected that the volume will be ready in 1908. This arduous task has been in Dr. PERRINE'S charge.

Comet *d* 1907, discovered by DANIEL, was the brightest comet that had been in good observing position since 1893. Advantage was taken of this fact to secure a splendid series of photographs. Exposures were made by Mr. DUNCAN on thirty-six nights, from July 10th to September 12th, seventy-one negatives in all. These photographs, forming as nearly continuous a series as the weather and the moonlight permitted, exhibit admirably the progressive changes occurring in the head and tail as perihelion was approached, and likewise several interesting phenomena of an irregular character. In general, the changes were very rapid. It is probable that the tails of one night were entirely replaced by tails composed of new matter on the following night. A noteworthy fact was that whenever any of the streamers appeared as curves, their convex sides were turned toward the other streamers, suggesting strongly that the particles in the tails repel each other. Only the negatives of July 10th and 11th recorded well-defined condensations in the tails. Fortunately, Professor BARNARD obtained a photograph of the comet on July 11th, at the Yerkes Observatory, a copy of which he kindly supplied to us. In the $2^h\ 25^m$ elapsing between the taking of the Yerkes and Lick plates, the displacement of the prominent condensation was very marked. Although the nucleus of the comet was approaching the Sun, the condensation receded from the Sun. Mr. DUNCAN found its velocity away from the nucleus to be 44^{km} per second, and from the Sun 15^{km} per second. Several less definite structures were observed on later plates. Two exposures having been made here on the same night, whenever possible, Mr. DUNCAN was successful in detecting outward motion in several cases; and the velocity of recession was always the greater for greater distances from the nucleus. This is as it should be, assuming their motion to be due principally to a continuously acting repulsive force emanating from the nucleus, or from the Sun, or from both.

Polarization observations of the comet, made by Messrs. DUNCAN and CAMPBELL, seemed to show that the proportion

of polarized light decreased rather rapidly as the comet approached the Sun; indicating that its light at first consisted largely of diffused sunlight and later mostly of light inherent to the comet or of sunlight reflected to us by large particles forming the nucleus.

The spectrum of the comet was studied by Mr. CAMPBELL. It was at first almost free from the bright bands of carbon and cyanogen, but in late August and early September these became very prominent. The best spectrograms showed the spectrum of the nucleus to be a close approximation to the solar spectrum (reflected sunlight, apparently not polarized strongly), and the spectrum of the coma to consist largely of a great number of bright lines.

The photography of comets, applied with great success, first by Professor BARNARD at the Lick Observatory and subsequently by observers at various stations, has made clear the fact, undoubtedly very significant, that the tails of these bodies undergo exceedingly rapid changes. It is not too much to hope that a thorough study of these internal changes will shed strong light on the origin, composition, and physical conditions of cometary bodies. Bright comets, naturally, keep to the region of the sky immediately surrounding the Sun, and for this reason it is seldom practicable for the same observer to secure more than one good photograph per night. In these days of astronomical co-operation, we cannot find a subject more worthy of co-ordinated effort on the part of different observatories than that of comet photography. It is high time that such an organization be perfected, to care suitably for the bright comets of the future. The interests of observers provided with telescopes suitable for photographic comets, both in this country and abroad, should be enlisted and organized, so that, as a comet is successively in position for these observers, covering a wide range of terrestrial longitudes, photographic records will be obtained suitable for subsequent comparison.

The general plans for the observatory were made in the late 70's and executed in the early 80's, at which time astronomers did not realize the important part that photography was destined to play in their researches. Consequently, when the institution was opened, on June 1, 1888, it did not possess

suitable apparatus and rooms for taking celestial photographs and for their measurement and study. Director HOLDEN proceeded energetically and wisely to transform the equipment to meet photographic requirements. Fortunately, gifts from outside sources, and such small sums as could be spared from the maintenance funds, provided for photographic telescopes, spectrographs, and measuring microscopes. Space suitable for the storage and study of photographs has been a pressing need, and the successive annual reports of Directors HOLDEN, KEELER, and CAMPBELL have drawn attention to this need. The last two legislatures appropriated small sums to begin such a building. With these funds a section of the building was erected in the late fall of 1907, of reinforced concrete. It includes three storage vaults on the first floor, and an enlarging room fifty feet long on the second floor: one third the space of the finished building as planned, erected at one half the total cost. It is hoped that the next Legislature will provide for its completion, in 1909.

The installation of the electric plant, begun under great and unnatural difficulties immediately following the earthquake and fire of April, 1906, was completed in June, 1907. A twenty horse-power gasoline engine, using distillate, is directly connected to the dynamo, which charges a storage battery of 128 cells, each having a capacity of 200 ampere hours. The battery serves as a reservoir of power, to be drawn upon as required. Apart from current for producing comparison spectra, maintaining the spectrographs at constant temperatures, lighting micrometers, and for other purely scientific work, it is drawn upon to turn the domes of the 36-inch refractor and the Crossley reflector, to wind their clocks automatically, to run the machinery in the instrument-making and carpenter shops, to operate two pumps in the water systems, to saw fuel for the community, and to illuminate all the buildings The entire plant is operating satisfactorily, and is a great addition to the resources of the observatory. In particular, the use of motors in winding clocks (automatically) and turning domes has perceptibly increased the observing efficiency.

A considerable list of minor scientific results and additions to equipment should, for completeness, be mentioned, but space is lacking.

W. W. CAMPBELL,
Director.

GENERAL NOTES.

Planetary Nebula with Variable Nucleus.—Professor BARNARD some years ago suspected a variation of the brightness of the nucleus of the planetary nebula N. G. C. 7662. In *Monthly Notices* R. A. S., April, 1908, he gives the observational evidence, mostly secured by himself in the last ten years with the 40-inch telescope, from which he finds a variation of three or four magnitudes and a period of about twenty-eight days. The nucleus is faint—near the limit of the great refractor—except for a few days of the four weeks, when it appears like a bright yellowish star of about the twelfth magnitude. Professor BARNARD finds confirmation of the variability from his own photographs in 1899 and 1900, and from early observations with the Rosse telescope and LASSELL'S four-foot reflector.

Professor TURNER (*loc. cit.*) finds that the data are fairly well satisfied by the period 27⅓ days.

Professor KAPTEYN has been elected an honorary member of the Royal Irish Academy.

The 7-inch Reinfelder-and-Hertel refractor of the Manora Observatory, Istria, Austria, is being offered for sale. Unusually good performance is reported for this instrument.

There seems little doubt that the faint object discovered by Mr. P. MELOTTE on Greenwich Observatory photographs in the region of *Jupiter* is a new satellite (VIII), with retrograde motion, and distance from *Jupiter* of about 20,000,000 miles.—*The Observatory*, May, 1908.

Mr. J. EWEN, of Edinburgh, has constructed a highly reflecting model of *Saturn* and his rings, which, when illuminated by a strong light in the plane of the rings, shows two tiny luminous knots on either side of the ball. Spinning the model causes the knots to shift inward, the shift increasing with the speed of rotation.—*The Observatory*, April, 1908.

M. P. Vincart, of Antwerp, can, with the naked eye, count thirteen of the *Pleiades* stars, and see *Jupiter's* third satellite at opposition.—*Journal* B. A. A., from *Nature* of March 19, 1908.

The Paris Academy of Sciences has appointed a committee to consider the feasibility of sending a signal at midnight each night from the wireless telegraph station on Eiffel Tower, to aid navigators at sea in determining their longitude.—*Science.*

The Rumford Committee of the American Academy has made a grant of one hundred dollars to Professor Joel Stebbins, of the University of Illinois, for his investigation on the use of selenium in photometry.—*Science.*

Notes from "Science."—The directorship of the Toulouse Observatory, vacant by the appointment of M Baillaud to the National Observatory, has been filled by the election of M. E. Cosserat.

M. H. Deslandres, who since 1897 has been assistant director of the observatory at Meudon, has been appointed director to succeed the late Dr. Janssen.

Professor H. Poincaré, professor of astronomy in the Paris Ecole Polytechnique, has retired with the title of honorary professor.

M. Maurice Hamy, of the Paris Observatory, succeeds the late Dr. Janssen as a member of the Paris Academy of Sciences.

Director Edwin B. Frost, of the Yerkes Observatory, University of Chicago, has been elected a member of the National Academy of Science, and Dr. Hugo Ritter von Seeliger, professor of astronomy in the University of Munich, has been elected a foreign associate by the same institution.

The Allegheny Observatory.—After a period of construction extending over a number of years the Allegheny Observatory, in its new location, is again making valuable contribution to the science of astronomy. Five parts of Volume I, *Publica-*

tions of the Allegheny Observatory, have recently been issued under the following titles:—

No. 1. "On the Distortion of Photographic Films."
No. 2. "A Simple Method for Reducing Spectrograms."
No. 3. "The Orbit of α *Andromedæ.*"
No. 4. "The Radial Velocity of ϵ *Ursæ Majoris.*"
No. 5. "The Orbit of *Algol* from Observations made in 1906 and 1907."

The authors of these investigations are Dr. FRANK SCHLESINGER (Director), Dr. R. H. CURTISS, and Mr. R. H. BAKER.

Volume I, No. 1 (April, 1908), of the *Astronomical Herald,* published by the Astronomical Society of Japan, was received recently. The title and table of contents are printed in English, but all of the text is in Oriental characters.

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ARRHENIUS, SVANTE. Worlds in the making. Harper and Brothers, New York. 1908. 8vo. Cloth. $1.60 net.

BELOPOLSKY, A. Untersuchung der Radialgeschwindigkeit des veränderlichen Sterns *Algol* (*β Persei*) in den Jahren 1905-1907. Mitteilungen der Nikolai-Hauptsternwarte zu Pulkowo. Band II, No. 22. Folio. 34 pp. Paper.

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HARTWIG, ERNST. Ueber den Antalgolstern *RW Draconis*. Sonderabdruck aus dem XIX und XX Bericht der Naturforschenden Gesellschaft. Bamberg. 8vo. 32 pp. Paper.

HARTWIG, ERNST. Ephemeriden veränderlicher Sterne für 1908. Leipzig. 1908. 8vo. 78 pp. Paper.

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KAPTEYN, J. C. On the number of stars of determined magnitude and determined galactic latitude. Publications of the Astronomical Laboratory at Groningen, No. 18. Groningen. 1908. 8vo. 54 pp. Paper.

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible Dues sent by mail should be directed to Astronomical Society of the Pacific, Students Observatory, Berkeley

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied Members are requested to preserve the copies of the *Publications* of the Society as sent to them Once each year a title page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A S P., Students Observatory, Berkeley, Cal who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience In a general way those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States The responsibility for the views expressed in the papers printed and for the form of their expression, rests with the writers, and is not assumed by the Society itself

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PUBLICATIONS ISSUED BI MONTHLY

(February April June, August October, December.)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco, California Subscription price, $5 00 per year

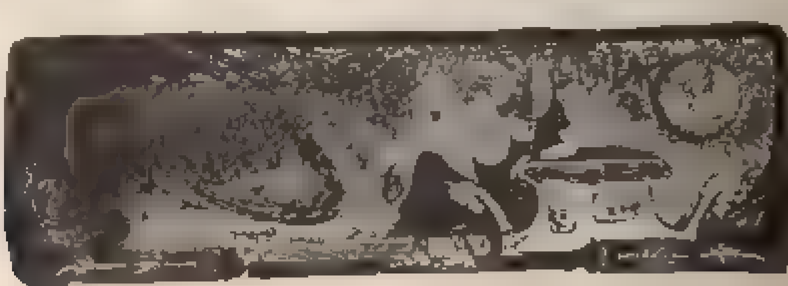

PLATE I

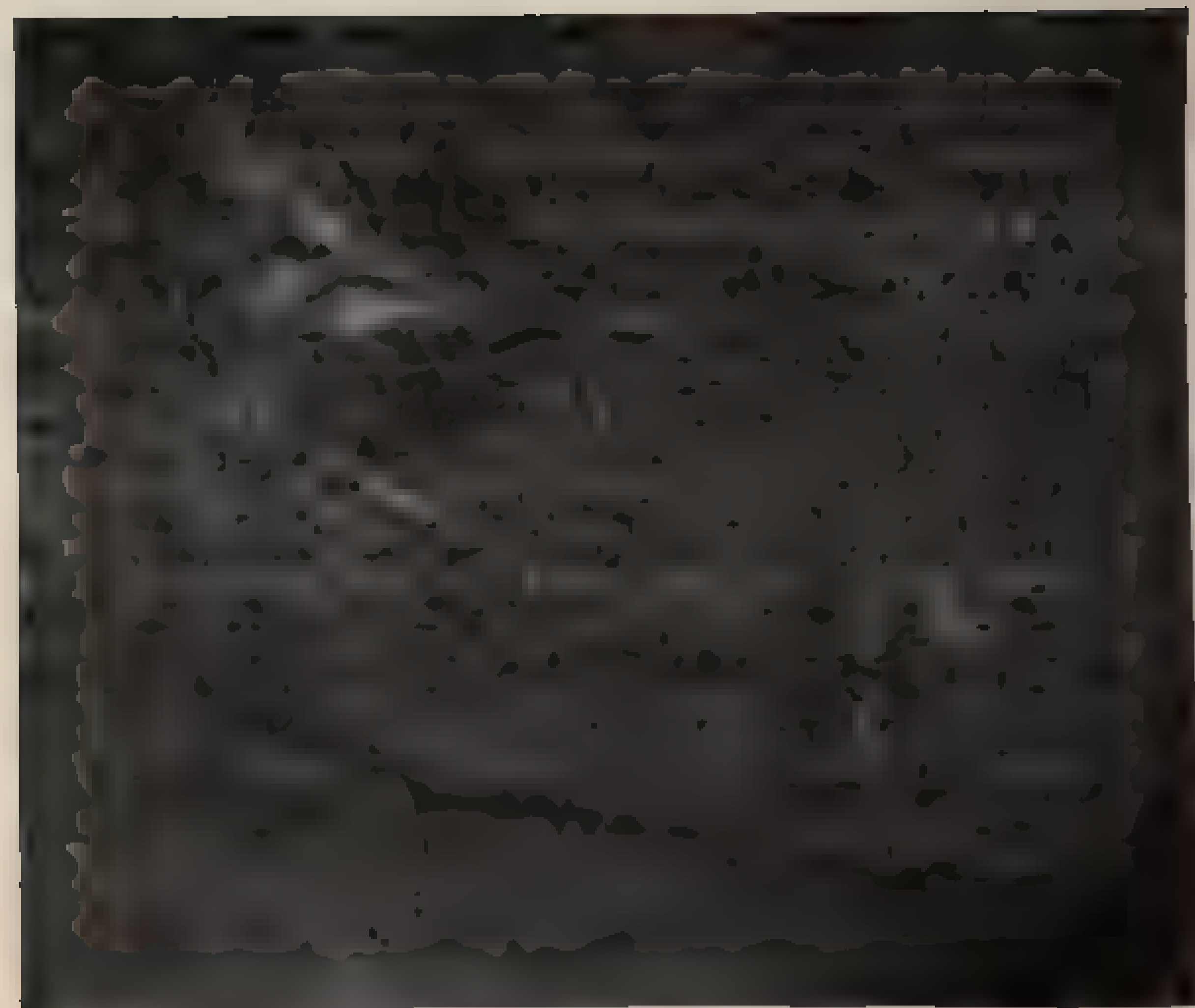

FIG. 1.—HYDROGEN FLOCCULI, PHOTOGRAPHED WITH THE $H\alpha$ LINE
1908, May 1, $4^{h} 48^{m}$ P.M. Scale: Sun's Diameter = 0.2 Meter

FIG. 2.—HYDROGEN FLOCCULI, PHOTOGRAPHED WITH THE $H\delta$ LINE

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XX. SAN FRANCISCO, CALIFORNIA, AUGUST 10, 1908. No. 121

SOLAR VORTICES.[1]

BY GEORGE E. HALE

The problem of interpreting the complex solar phenomena recorded by the spectroheliograph has occupied my attention since the first work with this instrument in 1892. The measurement of the daily motions in longitude of the calcium flocculi has led to several new determinations of the solar rotation,[2] and their areas, measured by a photometric method, are being used as an index to the solar activity. Various investigations on their forms at different levels,[3] their distribution in latitude and longitude, etc., have also been carried out. But the failure of the calcium flocculi to indicate the existence of definite currents in the solar atmosphere has been a disappointment.

The hydrogen flocculi, though occupying the same general regions on the Sun's disk, are distinguished from those of calcium by several striking peculiarities. In the first place, most of them are dark, while the corresponding calcium (H_2) flocculi are bright. Secondly, as I have recently shown,[4] they seem to obey a different law of rotation, in which the equatorial acceleration (better, the polar retardation) shared by the spots, faculæ and calcium flocculi, does not appear. A third peculiarity, briefly mentioned in previous papers, is

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[1] *Contributions from the Mount Wilson Solar Observatory*, No. 26.

[2] HALE and FOX, "The Rotation of the Sun, as Determined from the Motions of the Calcium Flocculi," Carnegie Institution (in press). FOX, *Science*, April 19, 1907. HALE, *Contributions from the Mount Wilson Solar Observatory*, No. 25; *Astrophysical Journal*, Vol. XXVII, p. 219, 1908.

[3] HALE and ELLERMAN, *Publications of the Yerkes Observatory*, Vol. III, Part I.

[4] HALE, *Contributions from the Mount Wilson Solar Observatory*, No. 25, *Astrophysical Journal*, Vol. XXVII, p. 219, 1908.

clearly visible on many hydrogen photographs. It is a decided definiteness of structure, indicated by radial or curving lines, or by some such distribution of the minor flocculi as iron filings present in a magnetic field (see, for example, *Astrophysical Journal*, Vol. XIX, Plates X and XII). First recognized at the beginning of our work with the hydrogen lines in 1903, this suggestive structure has repeatedly shown itself on the Mt. Wilson negatives. But its true meaning did not appear until the results described in this paper had been obtained.

With the Rumford spectroheliograph the hydrogen lines $H\beta$, $H\gamma$, and $H\delta$ were used Certain differences between the photographs, which seemed to depend upon the wave-length, pointed to the desirability of trying $H\alpha$ But plates sufficiently sensitive to red light were not to be had at that time, and therefore the experiment was postponed.

The extreme sensitiveness in the red of plates prepared according to a formula due to WALLACE[1] now renders it a simple matter to photograph the Sun with $H\alpha$. Some preliminary work with the spectroheliograph attachment of the 30-foot Littrow spectrograph of the tower telescope, in which I had the assistance of Mr. ADAMS, indicated that bright flocculi are more numerous and extensive when photographed with $H\alpha$ than when $H\delta$ is used. I then tried $H\alpha$ with the five-foot spectroheliograph of the Snow telescope, and immediately obtained excellent results. The images were stronger and of much better contrast than those given by $H\delta$. Moreover, the curved and radial structure surrounding sun-spots was so striking as to lead to the hope that important advances might be expected to follow from the systematic use of the $H\alpha$ line.

On account of the difference in curvature of $H\alpha$ and $H\delta$, these preliminary photographs, made with $H\delta$ slits, showed only a very narrow zone of the solar image. A new pair of slits, of suitable curvature for $H\alpha$, was accordingly made for the five-foot spectroheliograph, and as soon as these were ready I completed the adjustments of the instrument, with Mr. ELLERMAN'S assistance, and made comparative photo-

[1] *Astrophysical Journal* Vol. XXVI, p 299.

PLATE II

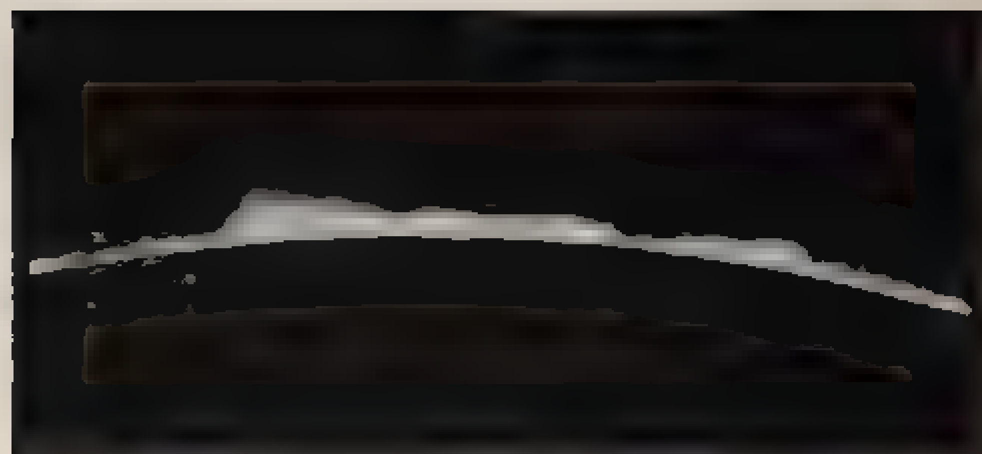
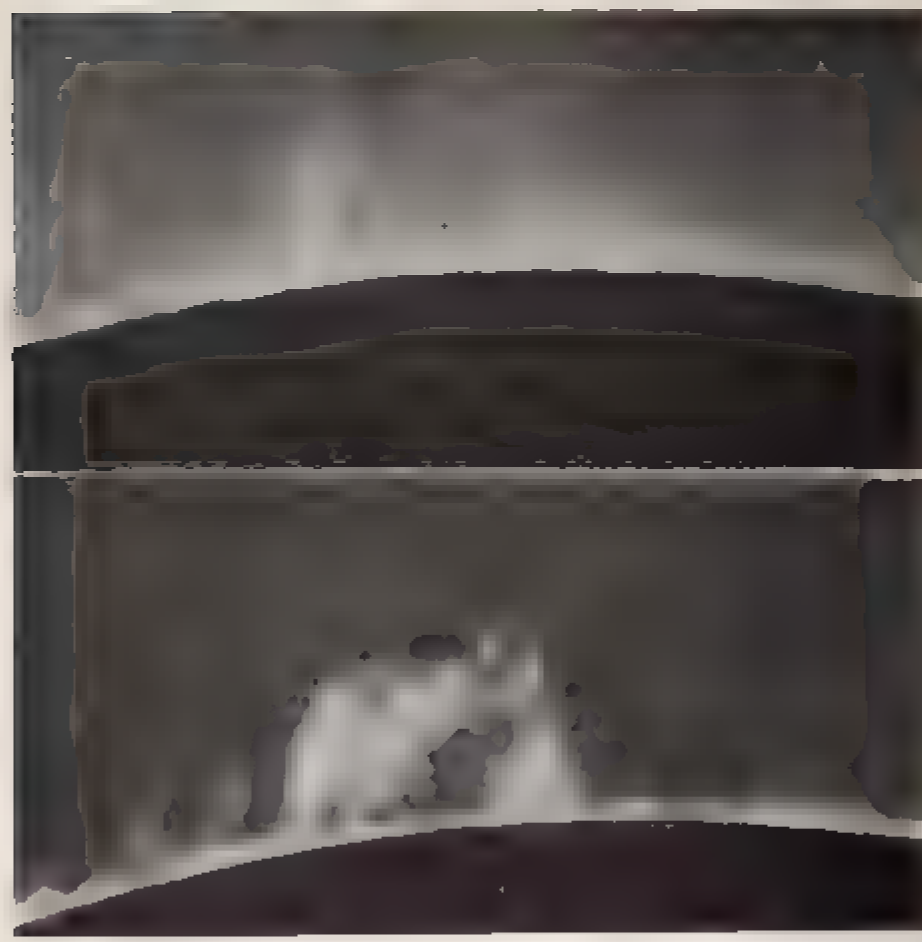


FIG. 1. PROMINENCES AT EASTERN LIMB OF THE SUN.
1908, May 26, 6^h 38^m A.M. Scale: Sun's Diameter = 0.3 Meter.



FIGS. 2 AND 3. PROMINENCES PHOTOGRAPHED WITH $H\delta$ (FIG. 2) AND $H\alpha$ (FIG. 3).
1908, April 3. Scale: Sun's Diameter = 0.3 Meter.

graphs of the entire disk with $H\alpha$ and $H\delta$. The differences exhibited by these plates are very marked. For example, a long dark flocculus, strongly shown by $H\alpha$, is represented on an $H\delta$ photograph by only a few of its most intense parts. In the case of bright flocculi, the differences are even more conspicuous, large luminous areas shown by $H\alpha$ being absent from the $H\delta$ plates. To eliminate errors arising from possible changes on the Sun between exposures, the photographs were taken in rapid succession, an $H\alpha$ plate between two of $H\delta$. In this way all doubts as to the genuineness of the observed differences were removed. Plate I illustrates the general character of these differences, concerning the cause of which we may now inquire.

It naturally occurred to me that photographs of a prominence at the Sun's limb, taken with the various hydrogen lines, would be likely to throw light on the question. Mr. Ellerman accordingly made a series of photographs of a prominence, using the lines $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$. The fall of intensity toward the violet was very marked, the faint $H\delta$ image bringing out only the brightest parts of the prominence as photographed with $H\alpha$ (Figs. 2 and 3, Plate II). $H\beta$ and $H\gamma$ gave intermediate results, approximating those obtained with $H\delta$.

It thus seems probable that the marked intensity of the $H\alpha$ flocculi results from the great strength of the $H\alpha$ line in the chromosphere and prominences. $H\delta$ is strong enough in the middle and sometimes in the upper chromosphere and in the lower parts of bright prominences, to show the hydrogen in these regions when projected on the disk. $H\alpha$, being much more intense, brings before us in plain view a higher region of the solar atmosphere, including the upper chromosphere and bright prominences. Whether these are to appear as bright or dark flocculi, when photographed against the disk, probably depends primarily upon their temperature, though the conditions may not be such as to permit the direct application of Kirchhoff's law.

But the photographs bring out a second fact of interest. Although, as has been stated, the flocculi are generally stronger on the $H\alpha$ plates, it cannot be said that these $H\alpha$ images are merely intensified $H\delta$ images, for there is an important point of

difference:[1] dark $H\delta$ flocculi are sometimes replaced on the $H\alpha$ plates by bright flocculi or by apparently neutral spaces. The condition of the hydrogen in such regions thus appears to be the same as in certain stars, whose spectra show $H\alpha$ bright and the more refrangible hydrogen lines dark.

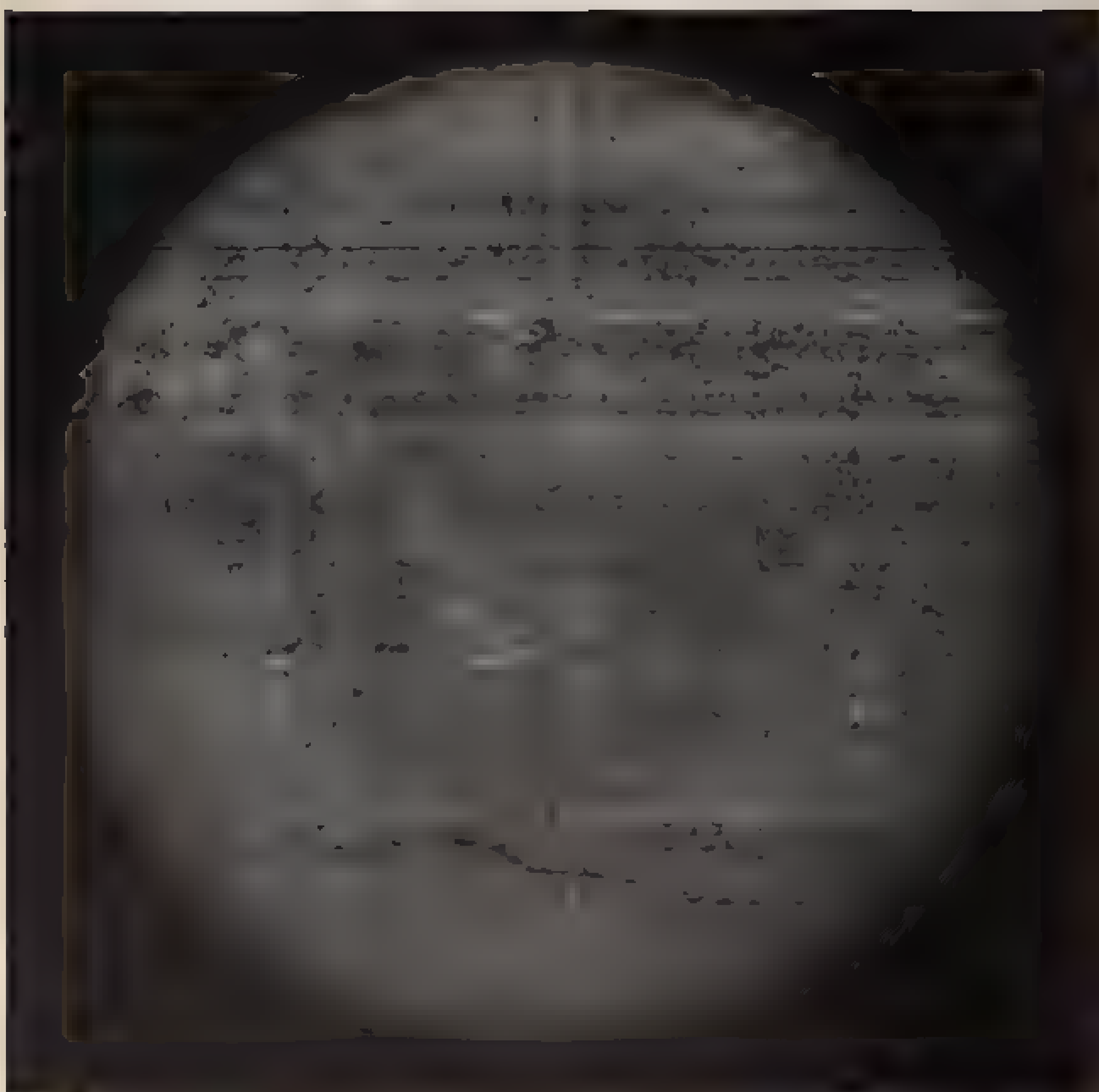
The importance of continuing the work of photographing the Sun with $H\alpha$ was obvious, and I immediately modified the daily programme of observations with this object in view. In the photography of the chromosphere and prominences at the limb, $H\alpha$ was substituted for the H line of calcium, since it was found to give stronger and sharper negatives. For the disk $H\alpha$ was adopted in place of $H\delta$, though work was continued with the latter line long enough to secure a series of photographs for comparison. Later, as more $H\alpha$ plates were needed, the daily series of photographs with the iron line λ 4046 was discontinued, and all of the observing time of the Snow telescope in the morning devoted to $H\alpha$ work. In the afternoon this line is also used most of the time, though one plate is made with H_1 and one with H_2 of calcium.

A serious difficulty at once presented itself. Previously only a few photographs had been taken during each of the best observing periods, which last less than two hours in the early morning and late afternoon. Between exposures the mirrors were shielded from sunlight, and electric fans kept a continuous blast of air directed upon them. Even with these precautions there would frequently be a marked change of focal length during an exposure lasting four minutes. The distortion of the mirrors increased during the observations, and strong evidences of astigmatism often appeared before they were completed. Except for occasional eruptions, the calcium, iron, and $H\delta$ flocculi change rather slowly in form, and one or two photographs taken daily with each line sufficed for the investigations in progress. In the case of $H\alpha$ it seemed probable that many photographs, separated by short time intervals, would be needed to register the phases of

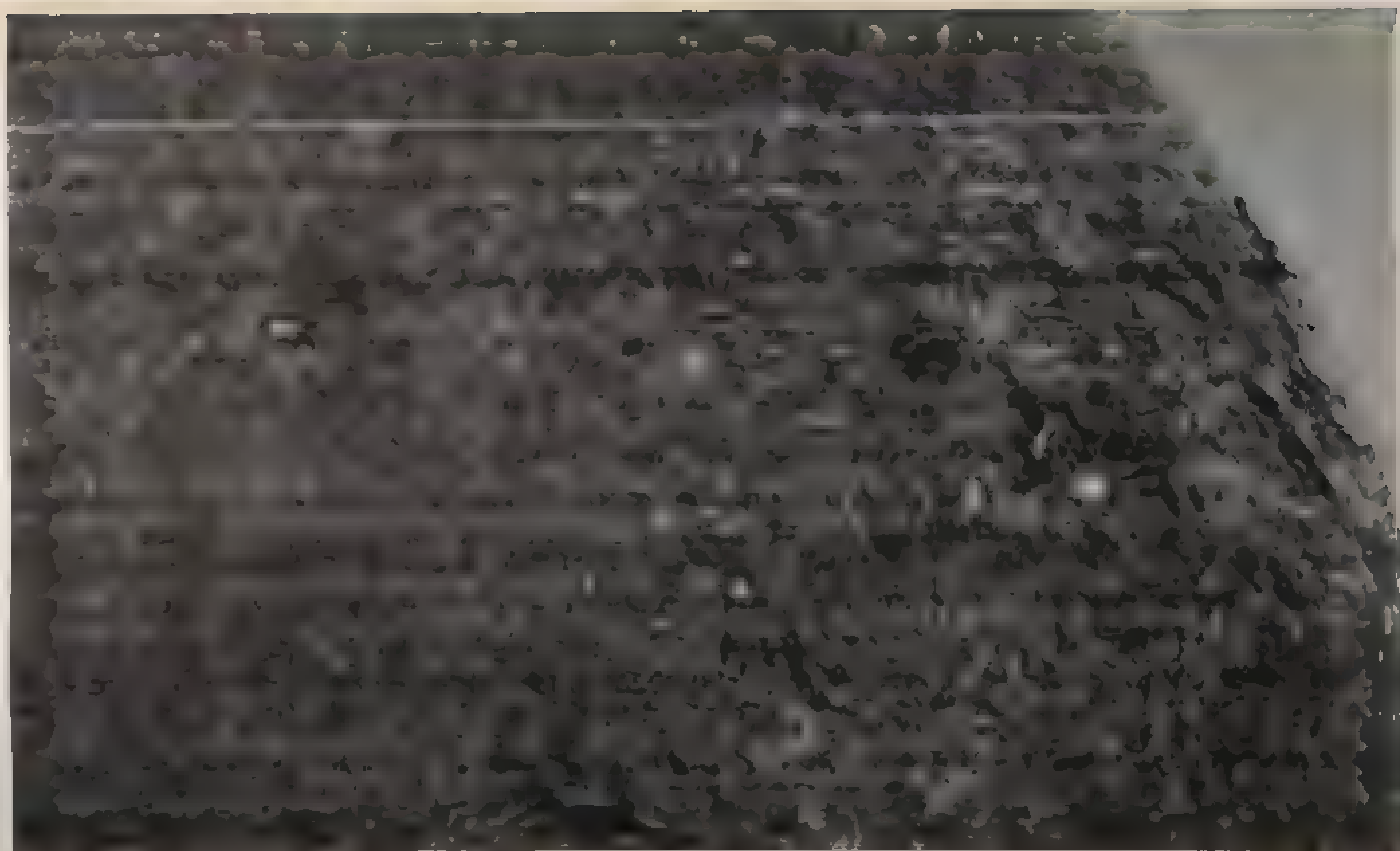
[1] I leave for future consideration the question whether the neutral regions on the $H\alpha$ plates are to be regarded as bright flocculi of reduced intensity. It will also be important to determine whether KAYSER's explanation of the appearance in a stellar spectrum of both bright and dark hydrogen lines (*Astrophysical Journal*, Vol. XIV, p. 313) will apply to solar phenomena.

[2] Except the short interval required to obtain a direct photograph.

PLATE III



THE SUN, SHOWING THE HYDROGEN ($H\alpha$) FLOCCULI
1908, April 30, $5^h\ 06^m$ P. M.



HYDROGEN ($H\alpha$) FLOCCULI SURROUNDING SUN SPOTS

1908, April 30, 5h 06m P. M. Large scale *negative* print showing portion of Plate XXXII, reversed east and west

Scale: Sun's Diameter = 0.[illegible] Meter

PLATE V

DIRECT PHOTOGRAPH OF THE SUN
1908, April 30, 6^h 25^m A. M.

rapidly changing phenomena. This would mean almost uninterrupted exposure of the mirrors to sunlight, and such serious distortion that the astigmatism would ruin the photographs.

At this point experience with the tower telescope came in to good advantage. The very thick mirrors used with this instrument are not appreciably distorted in sunlight; hence it seemed probable that by reducing the aperture of the Snow telescope mirrors the increase in their relative thickness would relieve the difficulty. I therefore commenced a series of experiments with different apertures, and finally adopted a 15-inch (38^{cm}) diaphragm for the cœlostat in place of the full aperture of thirty inches (76^{cm}). With this the focal length does not ordinarily change perceptibly during a single exposure. When the mirrors are in sunlight, with very brief interruptions, during a period of an hour, the focal length gradually increases, but the effect of astigmatism is hardly appreciable.

In the work with *Hδ*, the hydrogen flocculi could not be photographed with sufficient contrast unless the very slow "Process" plates (also used for H_1 and H_2) were employed. These plates gave excellent results with *Hα*, but could not be used after the aperture had been reduced to fifteen inches without undue increase of exposure time; hence it was necessary to substitute for them SEED'S "Gilt Edge" plates, which fortunately serve very well with this line. The first experiments with *Hα* were made about the middle of March. On March 28th the new slits were in place, and the first photographs of the entire disk were obtained. During April the weather was not very favorable, but on April 29th and 30th Mr. ELLERMAN, then in charge of the routine work with the five-foot spectroheliograph, secured some remarkably fine negatives. The one taken on April 30th is reproduced in Plate III. Apart from the whirls, which may be seen to better advantage in Plate IV, this photograph shows in projection an enormous prominence in the southern hemisphere. This also appears, though much less satisfactorily, on the *Hα* photograph of May 1st, and may be traced on the *Hδ* photograph of the same date (Plate I).

HALE, *Contributions from the Mount Wilson Solar Observatory*, No. [illegible]; *Astrophysical Journal*, Vol. XXVII, p. 204, 1908.

But, in spite of its great intensity and length, this prominence is of minor interest in comparison with the structure shown in Plate IV. This is so definite in form and so unmistakable in character as to satisfy the hopes aroused by the earlier photographs. It seems evident, on mere inspection of these photographs, that sun-spots are centers of attraction, drawing toward them the hydrogen of the solar atmosphere. Moreover, the clearly defined whirls point to the existence of cyclonic storms or vortices.

The most striking of these storms occupies an enormous area in the southern hemisphere, extending from the equator to about 35° south latitude and about 50° in length.[1] Near the center of this region, partly covered by clouds of bright hydrogen, lies the small spot-group shown (from a direct photograph) in Plate V. The corresponding H_2 photograph reveals a large calcium flocculus over the spot-group (Plate VI), but this, though of great size, appears to differ in no essential particular from ordinary calcium flocculi, and gives no evidence of gyratory motion.

A good $H\alpha$ photograph was obtained on April 29th, but it was badly stained in the sensitizing process, and many of the flocculi are hidden by streaks on the negative. Fortunately, the greater part of the large storm area is fairly well shown, so that comparisons with the afternoon photograph of April 30th may be made in the stereocomparator (using the monocular attachment). On account of the changes in form of the flocculi during this interval, the identification of objects suitable for measurement is very difficult and uncertain. Three independent determinations of the positions of certain flocculi on the two plates have been made by Miss Ware. The objects identified on both dates were marked by small dots of ink on the glass side of the negative, and their latitude and longitude measured with the heliomicrometer. When reduced to the same epoch (using for the value of the daily angular motion $\xi = 14°.5$, derived from the measurement of 828 points on thirty-five $H\delta$ plates), the plotted results seem to show the existence of a gyratory motion, in a direction opposite to that of the hands of a watch (north, east, south, west). Although

[1] A large-scale plate showing this storm will appear in this *Contribution* when separately printed. It is unfortunately too large for the page of these *Publications*.

PLATE VIII

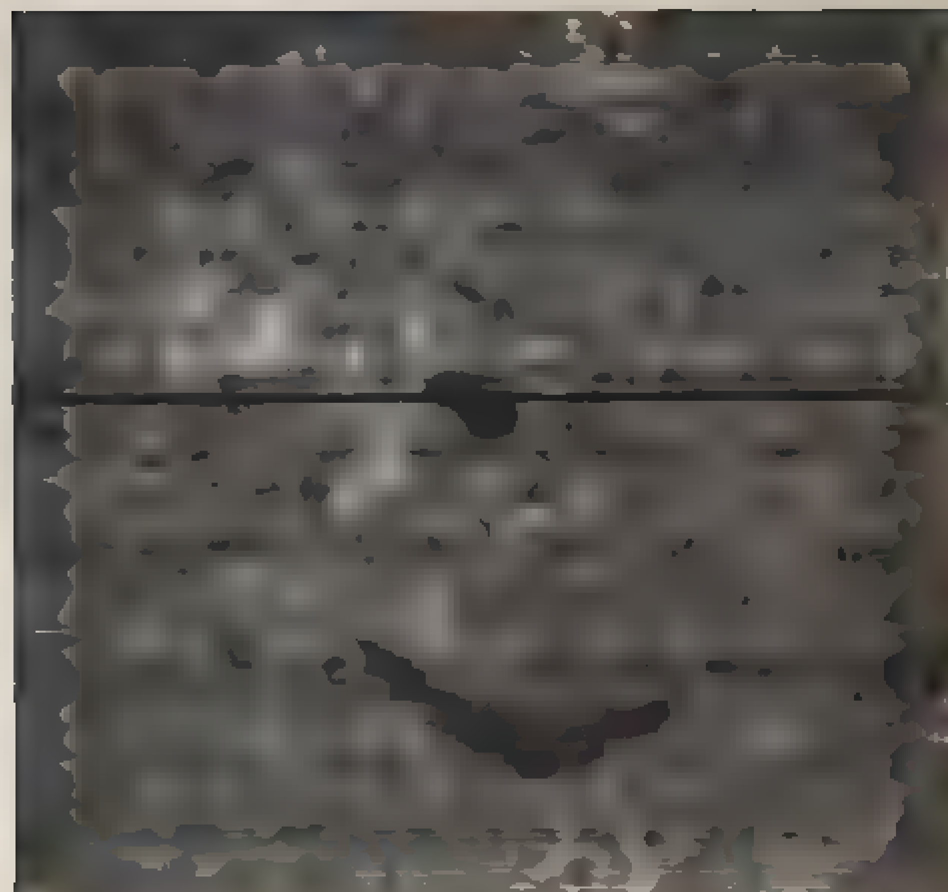


FIG. 1. SUN-SPOT AND HYDROGEN ($H\alpha$) FLOCCULI
1908, June 3, $4^h\ 58^m\ 16^s$ P. M. Scale: Sun's Diameter = 0.3 Meter

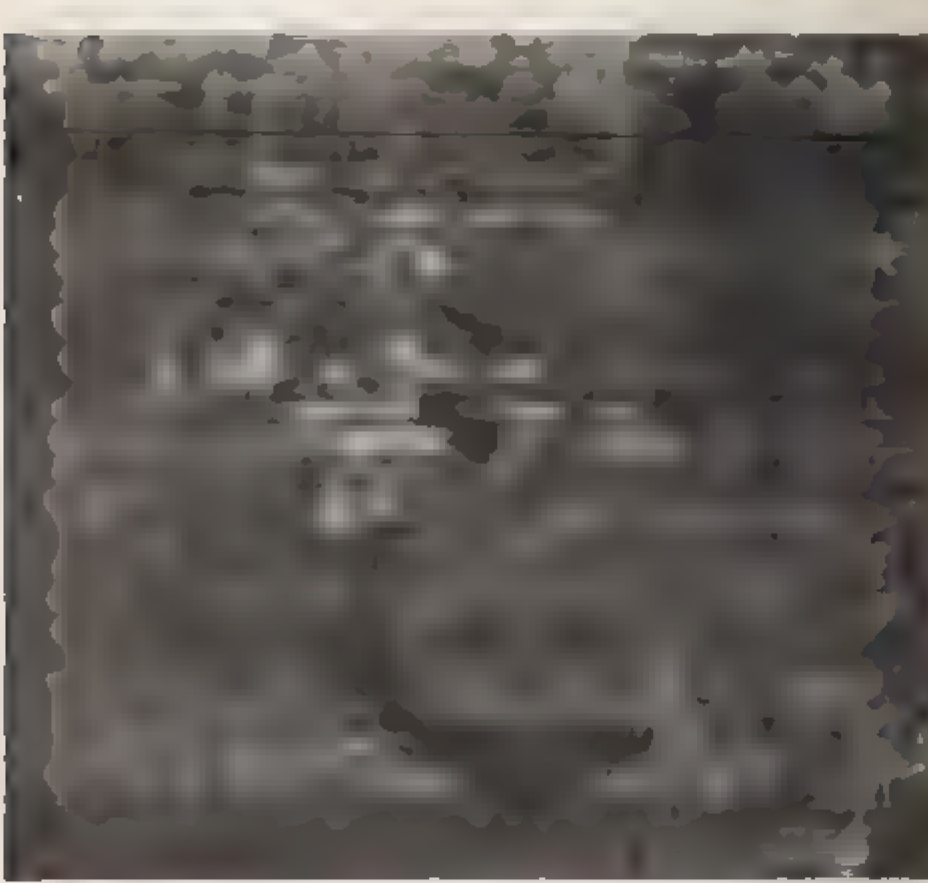


FIG. 2. SUN-SPOT AND HYDROGEN ($H\alpha$) FLOCCULI
1908, June 3, $5^h\ 13^m\ 54^s$ P. M. Scale: Sun's Diameter = 0.3 Meter

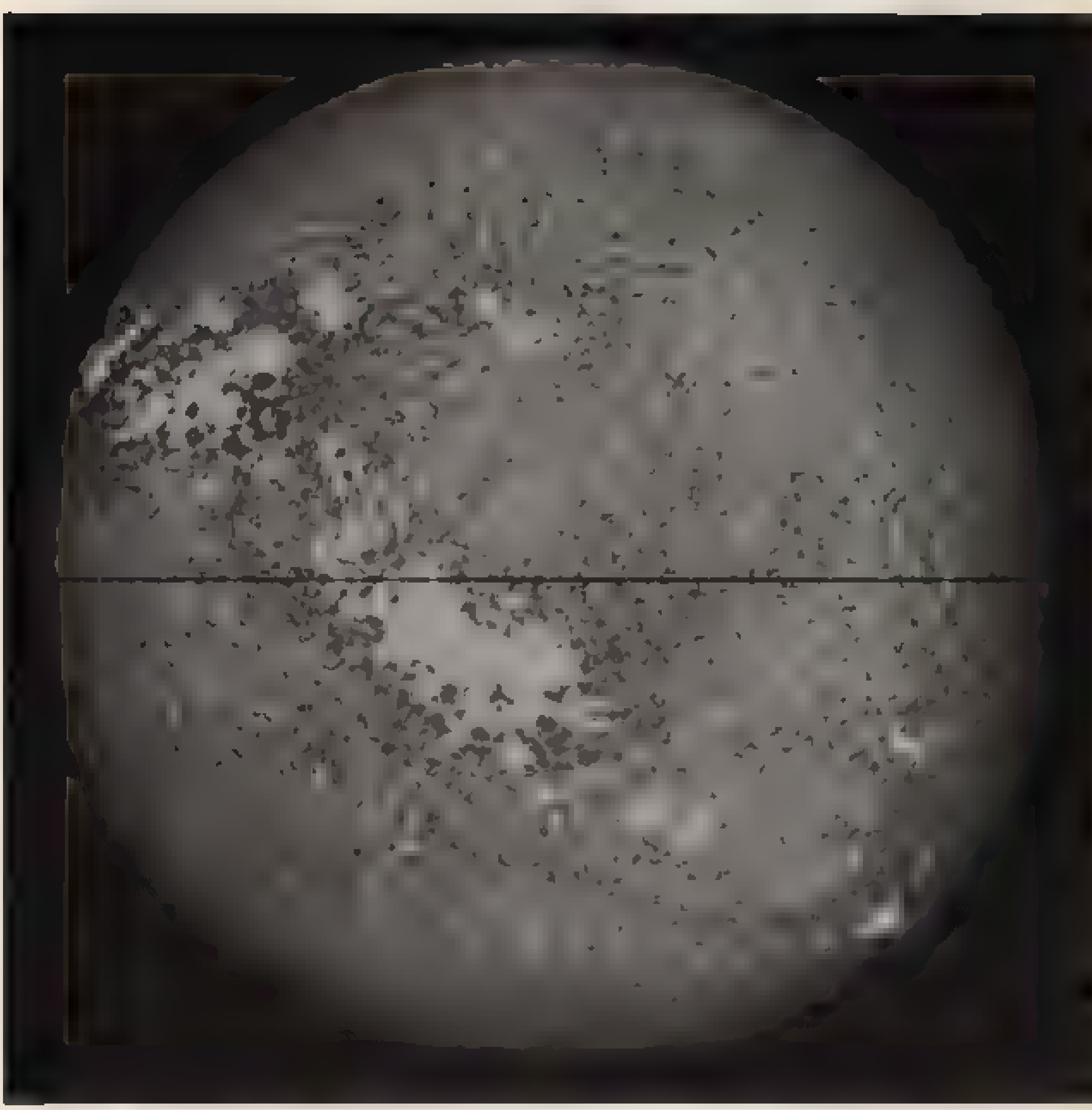
most of the points in a given region appear to move together, there are a sufficient number of apparently opposed motions to weaken seriously the value of the evidence. Unfortunately, an $H\delta$ plate taken on the morning of April 30th is not sharp enough to assist in the identifications. Further discussion of these plates is therefore postponed until additional data become available. On account of the complex character of such storms, a large number of photographs, taken at sufficiently short intervals to permit the flocculi to be identified with certainty, will be required to give satisfactory results. As our recent plates show that these storms are of common occurrence, and probably accompany every group containing several spots, there should be no difficulty in obtaining suitable photographs.

In the present paper I wish to illustrate the phenomena recorded with the aid of $H\alpha$ in the neighborhood of a spot which reached the east limb of the Sun at 8^h 16^m A.M. on May 26th, 1908. A photograph of this spot, made by myself with $H\alpha$ on May 29th, at 4^h 26^m P.M., Pacific Standard Time, is reproduced in Fig. 1, Plate VII. The whirl structure, which is clearly shown by this photograph, is also very distinct, though of somewhat different form, on the photograph of May 28th. It is interesting to inquire as to the probable level of the region in which this whirl occurred, and the height of the long dark flocculus south of the spot. For this purpose we may examine photographs of the chromosphere and prominences at the limb, taken on May 25th, 26th, and 27th. In the first of these, made on May 25th, at 9^h 18^m A.M. (No. 4142), a long, narrow prominence, extending toward the north, rises from the limb at position-angle 92°, a point about one degree north of where the spot would be. It makes an angle of about 12° with the limb, and fades out at the upper end, its length being approximately 90″ (geocentric) There are other small filamentary prominences in the region extending about 7° north of the spot, and smaller elevations in the chromosphere to the south At position-angle 98° a bright prominence rises to a height of about 20″, and then slopes to the chromospheric level at position-angle 107°. Near its southern end is an independent filamentary prominence about 55″ high On May 26th, at 6^h 38^m A.M. (No. 4144), the prominences shown in Fig. 1,

Plate II. were photographed at the east limb. The lowest point in the chromosphere on this photograph corresponds to the position (P. A. 93°) where the spot crossed the limb about two hours later. It will be seen that these prominences, which extend from position-angle 82° to 106°, cover much of the region in which the whirl structure of Plate VII appears. The prominence south of the spot is very bright and its highest point reaches an elevation of about 35″. On May 27th, at $5^h\ 22^m$ P.M. (No. 4152), a prominence about 25″ high extends from position-angle 105° to 109°. This is doubtless the eastern extremity of the strong flocculus in Plate VII, which may there be seen curving toward the spot.

We may now pass in rapid survey the more important photographs of the disk. On May 28th, at $6^h\ 58^m$ A.M. (No. 4157), the spot is near the east limb and the whirls are well shown. To the east of the spot is a long, narrow line of bright hydrogen. On May 29th, at $6^h\ 24^m$ A.M. (No. 4171), the whirls are very distinct and differ in many respects from those shown on May 28th. Eruptive regions of bright hydrogen are seen southeast and west of the spot. The eastern end of the long, dark flocculus is changing in form, and bridges are appearing over the spot. Negative No. 4175, taken $1^h\ 10^m$ later, seems to show distinct changes in the whirls, though they are not measurable. On May 29th, at $4^h\ 26^m$ P.M. (No. 4176), the whirls resemble those shown in negative No. 4175, but exhibit some marked changes. An eruption, which appears on the former plate southeast of the spot, continues, but is changed in form and less brilliant than before. A strong eruption, of peculiar form, appears southwest of the spot, and bright hydrogen to the northeast. Strong dark flocculi have also developed at many points around the spot. The eastern end of the long, dark flocculus is still changing, and a projection appears west of its center (see Plate VII). A negative taken on the same day, at $5^h\ 13^m$ P.M. (No. 4178), shows further changes both in the bright and dark structure, especially in the region southwest of the spot. A fork has developed in the western end of the long, dark flocculus, and a small but very dark flocculus appears just west of the spot. Another photograph (No. 4179), the first exposure of which was made at $5^h\ 20^m$ P.M., shows a bright eruption west of the spot, where the small,

PLATE VI



The Sun, Showing the Calcium (H_2) Flocculi
1908, April 30, $4^h 43^m$ P. M.

PLATE VII

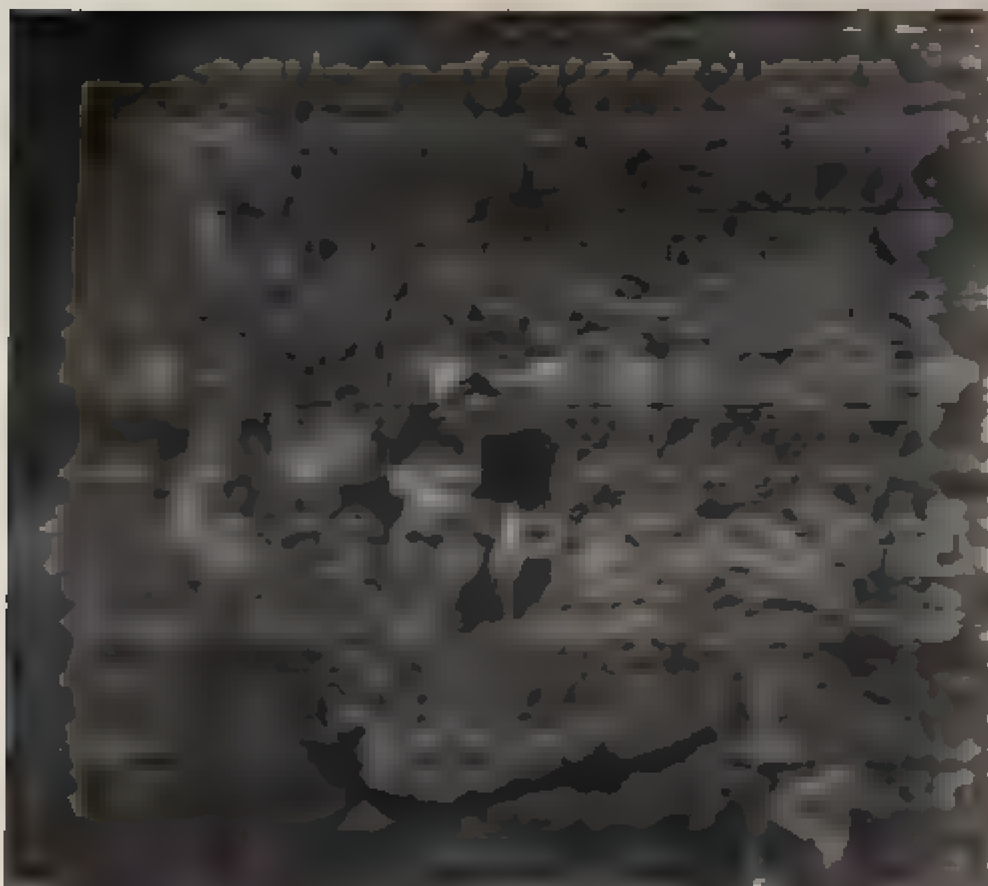


FIG. 1. SUN-SPOT AND HYDROGEN ($H\alpha$) FLOCCULI
1908, May 29, $4^h\ 26^m$ P.M. Scale: Sun's Diameter = 0.3 Meter

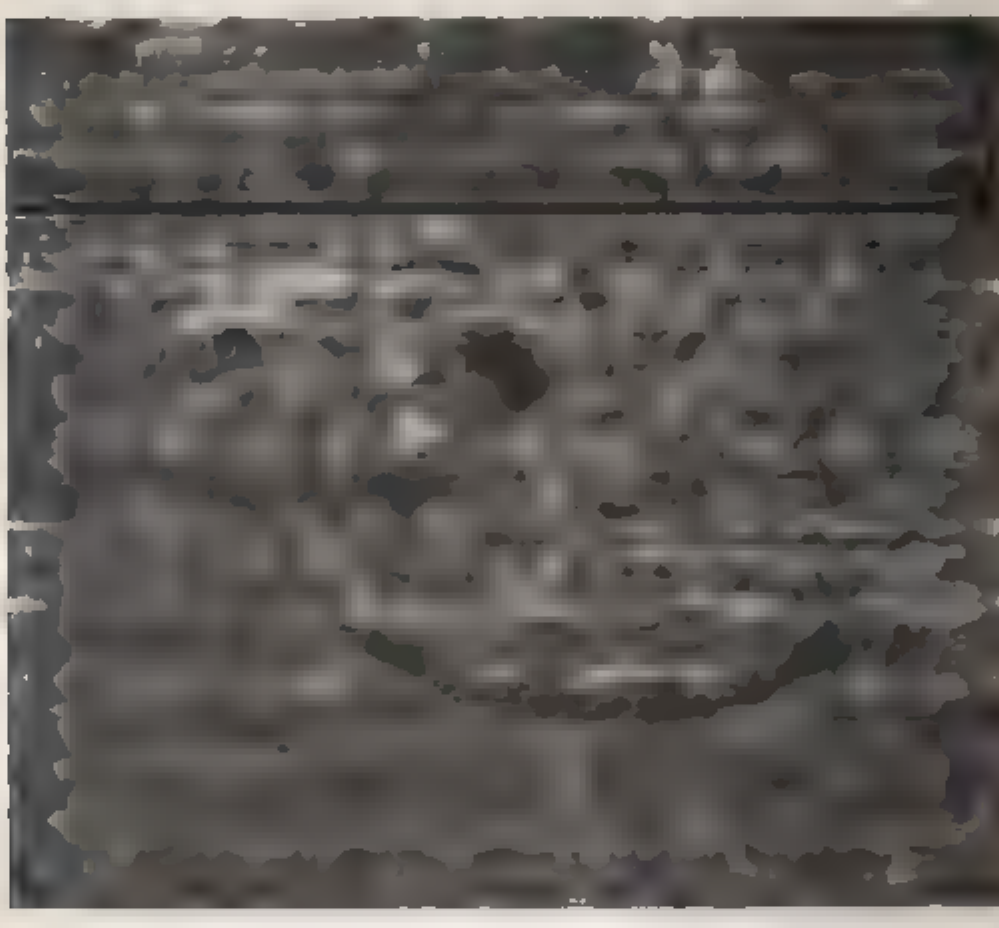


FIG. 2. SUN-SPOT AND HYDROGEN ($H\alpha$) FLOCCULI
1908, June 2, $6^h\ 10^m$ A.M. Scale: Sun's Diameter = 0.3 Meter

dark flocculus appears on No. 4178. The eruption underwent considerable change of form while the five exposures on this plate, separated by intervals of a few minutes, were being made. At 6^h 04^m P.M. negative No. 4181 shows that the eruption had subsided, and brings out other definite changes in structure near the spot. The small, dark flocculus has disappeared. On May 31st, at 8^h 00^m A.M. (No. 4188), the fork at the western extremity of the long, dark flocculus has partially closed. No eruptions appear west of the spot, but there are bright ones to the southeast. Other important changes are evident, and the two bridges across the spot are conspicuous. On June 1st, at 6^h 30^m A.M. (No. 4189), the fork at the western end of the long, dark flocculus appears more nearly as it did in negative No. 4181, and the two bridges over the spot are very marked. A negative taken fifteen minutes later (No. 4190), shows distinct changes, especially in the region south and southeast of the spot. At 5^h 08^m P.M. of the same day negative No. 4193 shows a more distinct whirl near the spot, and the long, dark flocculus appears to be growing shorter at its eastern end. On June 2d, at 6^h 10^m A.M. (No. 4196), the whirling structure is very marked and more nearly symmetrical about the spot, which is divided into two parts (Fig. 2, Plate VII). At 7^h 27^m A.M. (No. 4198), the whirl is also very marked and somewhat changed in form.

Up to this time the changes, while in many cases rapid, were not especially violent. On June 3d, in an interval of about ten minutes, a remarkable transformation occurred. The long, dark flocculus, which had been gradually changing in form and position, was suddenly drawn into the spot. As Fig. 2, Plate VII, illustrates, the whirls were very conspicuous on the preceding day. A series of photographs, nine of which were made on negative No. 4201, between 4^h 48^m 09^s P.M. and 5^h 13^m 54^s P.M., and one, showing the entire disk, on negative No. 4202 at 5^h 22^m P.M., records the changes which took place during this time. These photographs were taken by Dr. C. E. St. John, who joined the observatory staff in May, and is sharing with me the observational work with the five-foot spectroheliograph during Mr. Ellerman's absence on vacation. Three of these have been selected for reproduction. Fig. 1, Plate VIII, is enlarged from a photograph made at

$4^h\ 58^m\ 16^s$ P.M. (time of transit of spot across collimator slit of spectroheliograph). At $5^h\ 01^m\ 21^s$ the large, dark flocculus is apparently unchanged in form. At $5^h\ 04^m\ 21^s$ a photograph, which is not quite so well defined, gives no certain evidence of change. The next photograph, made at $5^h\ 07^m\ 06^s$, clearly shows the development of a fork at the eastern end of the flocculus, with traces of a very faint curved extension toward the larger spot. The position of the end of the fork (C), as measured on this photograph, is given below, but the extension is too faint to be measured with certainty. The next photograph, made at $5^h\ 10^m\ 52^s$, shows the fork and part of the extension, but the definition is poor and the position of the end of the extension uncertain. The last photograph on this plate, made at $5^h\ 13^m\ 54^s$, is reproduced in Fig. 2, Plate VIII. This admits of fairly satisfactory measurement, the results of which are given below. The spot region on negative No. 4202, made at $5^h\ 22^m$ P.M. (time of transit of spot), is reproduced in Fig. 1, Plate IX. Here the definition and contrast are also poor, but the extension, reaching nearly to the spots, is sufficiently well shown, as well as a dark flocculus which developed southeast of the smaller spot.

With the aid of the monocular attachment of the stereocomparator, I have made a careful examination of all the photographs, and Miss WARE has measured the positions of the long, dark flocculus with the heliomicrometer. If we call *A* the western extremity of this flocculus, *B* its eastern extremity, and *C* its point of nearest approach to the spot, we have the following results of the measurements, which also include the positions of the two spots:—

TABLE I.

Negative No.	Date	Point	Longitude	Latitude	Remarks
4176	May 29, 1908	A	32°.0 E	5°.8 S	B and B′ are the two extremities of eastern end of flocculus.
	$4^h\ 26^m$ P.M.	B	48.6	13.6	
		B′	46.7	12.8	
		Spot	45.8	3.0	
		Spot	44.4	3.1	
4189	June 1, 1908	A	3.9 W	5.5 S	
	$6^h\ 30^m$ A.M.	B	13.0 E	13.1	
		Spot	10.2	2.3	
		Spot	8.6	2.6	

PLATE IX

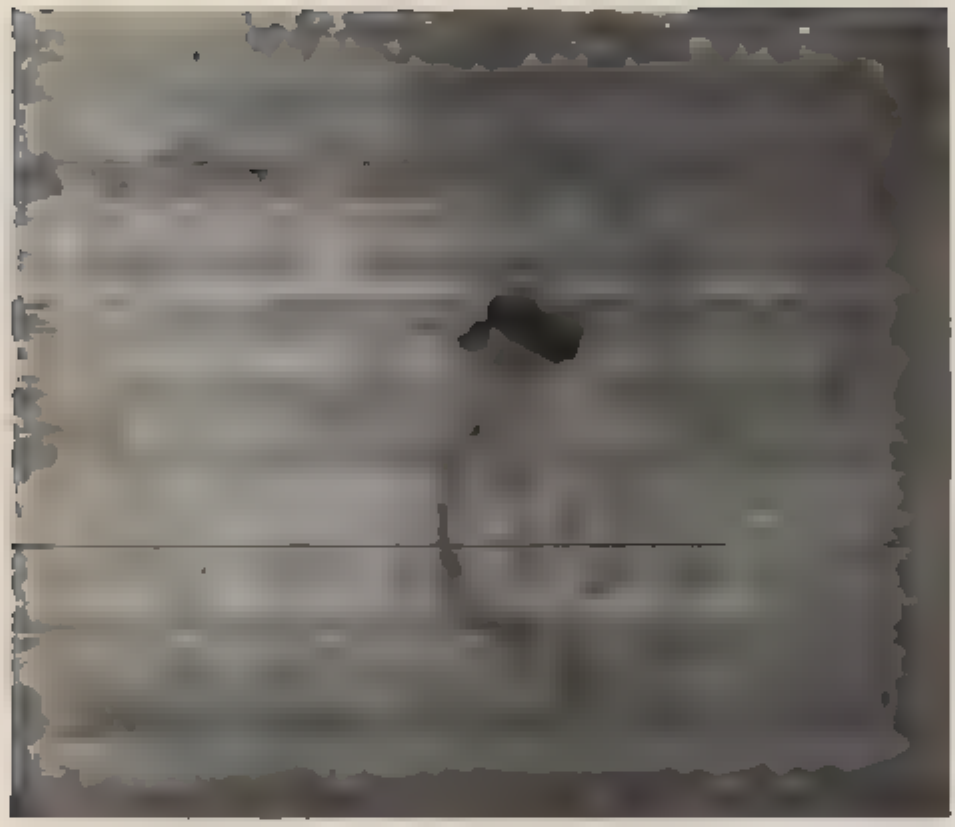


FIG. 1.—SUN-SPOT AND HYDROGEN ($H\alpha$) FLOCCULI
1908, June 3, 5^h 22^m P. M. Scale: Sun's Diameter = 0.3 Meter

FIG. 2.—SUN-SPOT AND HYDROGEN ($H\alpha$) FLOCCULI
1908, June 4, 6^h 12^m A. M. Scale: Sun's Diameter = 0.3 Meter

TABLE I—*Continued.*

Negative No.	Date.	Point.	Longitude.	Latitude.	Remarks.
4193	June 1, 1908	A	9°.7 W	4°.0 S	
	5^h 08^m P.M.	B	6 .4 E	12 .9	
		Spot	3 .5	3 .0	
		Spot not measurable.			
4196	June 2, 1908.	A	16 .9 W	5 .5 S	A and A′ are the two extremities of western end of flocculus.
	6^h 10^m A.M.	A′	16 .2	4 .5	
		B	2 .9	12 .4	
		Spot	2 .8	2 .8	
		Spot	4 .1	3 .1	
4201, Exp. 5.	June 3, 1908	A	38 .3 W	5 .8 S	
	5^h 01^m 21^s P.M.	B	23 .9	11 .1	
		Spot	22 .5	2 .6	
		Spot	24 .2	2 .7	
4201, Exp. 6.	June 3, 1908	A	35 .8 W	8 .2 S	
	5^h 04^m 21^s P.M.	B	23 .6	11 .2	
		C	25 .5	11 .1	
		Spot	22 .5	2 .6	
		Spot	24 .4	2 .8	
4201, Exp. 7.	June 3, 1908	A	35 .9 W	8 .1 S	
	5^h 07^m 06^s P.M.	B	23 .5	11 .0	
		C	24 .0	9 .2	
		Spot	22 .5	2 .5	
		Spot	24 .4	2 .7	
4201, Exp. 9.	June 3, 1908	A	35 .5 W	8 .0 S	
	5^h 13^m 54^s P.M.	B	23 .6	11 .0	
		C	23 .6	6 .2	
		Spot	22 .6	2 .6	
		Spot	24 .4	2 .7	
4202	June 3, 1908	C	23 .0 W	3 .5 S	C approaches eastern spot.
	5^h 22^m P.M.	C′	23 .8	3 .4	C′ approaches western spot.
		Spot	24 .5	2 .6	
		Spot	22 .7	2 .5	

If we now take the measured differences in longitude and latitude of the large spot and the points *A*, *B*, and *C* respectively, and compute the corresponding distances, we have the results given in Table II:—

TABLE II.

No.	Date.	Longitude. A—Spot.	B—Spot.	C—Spot.	Latitude. A—Spot.	B—Spot.	C—Spot.	Distance. A—Spot.	B—Spot.	C—Spot.
4176	May 29, 4^h 26^m P.M.	+12°.4	—4°.2		+2°.7	+10°.5		12°.7	11°.3	
4189	June 1, 6 30 A.M.	+12 .5	—4 .4		+2 .9	+10 .5		12 .8	11 .4	
4193	June 1, 5 08 P.M.	+13 .2	—2 .9		+1 .0	+9 .9		13 .2	10 .3	
4196	June 2, 6 10 A.M.	+12 .8	—1 .2		+2 .4	+9 .3		13 .0	9 .4	
		+12 .1			+1 .4			12 .1		
4201	June 3,—									
	Exp. 5, 5 01 21 P.M.	+14 .1	—0 .3		+3 .1	+8 .4		14 .4	8 .4	
	Exp. 6, 5 04 21 P.M.	+11 .4	—0 .8	+1°.1	+5 .4	+8 .4	+8°.3	12 .6	8 .4	8°.4
	Exp. 7, 5 07 06 P.M.	+11 .5	—0 .9	—0 .4	+5 .4	+8 .3	+6 .5	12 .7	8 .3	6 .5
	Exp. 9, 5 13 54 P.M.	+11 .1	—0 .8	—0 .8	+5 .3	+8 .3	+3 .5	12 .3	8 .3	3 .6
4202	June 3, 5 22 P.M.			C — E. Spot =0 .3 C′— W. Spot =0 .7			C — E. Spot =0 .8 C′ — W. Spot =1 .0			C — E. Spot =1 .0 C′— W. Spot =1 .1

These results show that the long, dark flocculus gradually shortened, its eastern extremity apparently moving inward along the flocculus, while the distance of its western extremity from the spot did not change in a systematic manner. Accuracy of measurement is out of the question, as the flocculus varied so much in form from day to day that there can be no certainty in the identification of points that appear to correspond. A comparison of the series of photographs taken during the period of rapid development shows that the form and position of the main body of the flocculus did not greatly alter in this short interval, though the maximum of intensity moved rapidly toward the spots, leaving the body of the flocculus very faint. Even on these photographs, however, the velocity of the motion toward the spot cannot be precisely measured, partly because of the difficulty of determining where the extension ends, and also because the time of the beginning of the phenomenon doubtless did not exactly coincide with the moment of exposure 6. Between exposures 6 and 7 we find for the point *C* a change of 1°.9 in latitude and 1°.5 in longitude. This corresponds to a motion of 2′.4 in 195 seconds, or 177^{km} per second. Between exposures 7 and 9, in an interval of 408 seconds, there was a change of 3°.0 in latitude and 0°.4 in longitude, giving a velocity of 86^{km} per second. Eight minutes later[1] the extension had divided and moved nearly to the spots, the resultant motion for each extremity being 2°.8, giving a velocity of 71^{km} per second.

In order to check these measures, the stereocomparator was used to mark all of the points on a single plate which was then measured differentially. The resulting velocities came out 140^{km}, 86^{km}, and 76^{km} per second respectively. Since the errors due to imperfect superposition in the stereocomparator should not differ markedly from those arising from a similar source in the heliomicrometer, the second set is given the same weight as the first. The differences among the three velocities cannot be trusted, though the evidence favors the view that the first velocity was actually higher than the others. The mean of the six measures (106^{km}) will at least serve to give the order of the maximum velocity in the vortex.

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[1] The time of negative No. 4202 is recorded only to the nearest minute.

The appearance of the spot and surrounding region thirteen hours after the rapid changes described above is shown in Fig. 2, Plate IX. The straight radial lines in this photograph are in marked contrast to the curved structure previously shown. The eastern of the more plainly marked radial lines is found by measurement to be a short distance to the east of the extension from the large flocculus to the spots shown in Fig. 2, Plate VIII. The forked connection to the two spots has disappeared and a strong, dark flocculus has developed at the southern extremity of the radial line, mainly on its eastern side. With the stereocomparator the main body of the large flocculus is found to resemble its former appearance in some particulars, but the distribution of intensities is very different and many changes in outline have occurred. In the photograph of June 5th, at 7^h 05^m A.M. (No. 4220), the radial structure surrounding the spots is greatly altered and the flocculus, no longer recognizable, has developed a large extension toward the west (Fig. 1, Plate X[1]). A notable feature of this photograph is the amount of bright eruptive hydrogen in the region surrounding the two spots. Some eruptive matter also appears in the photographs of the preceding day, but here it is greatly augmented. A photograph taken on the same day, at 5^h 19^m P.M. (No. 4227), is reproduced in Fig. 2, Plate X. It will be seen that the eruptions continue, and that the dark flocculi have undergone further important changes. The most notable of these is the connection which appears to be re-established between the two spots and the dark flocculus south of them. Apparently the dark hydrogen is again being drawn into the spots. On June 7th, at 7^h 56^m A.M. (No. 4244), a faint prominence appears on the limb south of the position of the spot. On June 8th, at 7^h 42^m A.M., negative No. 4252 shows a group of prominences closely resembling in form those reproduced in Fig. 1, Plate II, but very much less brilliant. On June 9th no prominence was photographed in this region.

As already remarked, the distance from the spot of the western extremity of the large flocculus did not vary systematically The eastern extremity, on the contrary, commenced

[1] There is a defect in this plate near the spots.

PLATE X

Fig. 1.—Sun-Spot and Hydrogen ($H\alpha$) Flocculi
1908, June 5, $7^h\ 05^m$ A.M. Scale: Sun's Diameter = 0.3 Meter

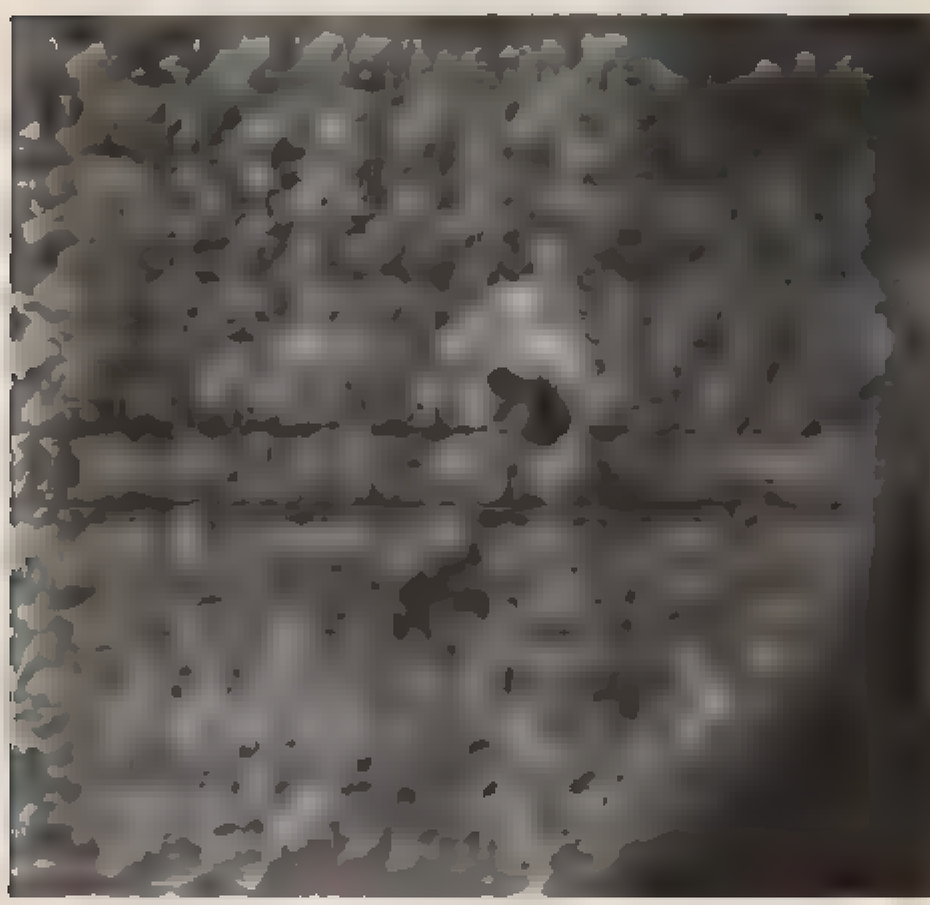

Fig. 2.—Sun-Spot and Hydrogen ($H\alpha$) Flocculi
1908, June 5, $5^h\ 19^m$ P.M. Scale: Sun's Diameter = 0.3 Meter

on June 1st to approach the spot, and continued to do so until the sudden change occurred on June 3d. Up to this time the velocity, instead of showing signs of acceleration, was apparently retarded, but the changing form of the flocculus leaves this point uncertain. On the photograph of May 29th (No. 4176) the whirl is most conspicuous north of the spot, where its extreme distance is about equal to that of the western end of the large flocculus. Apparently, however, the flocculus did not fall completely under the influence of the vortex until June 1st, when its eastern extremity was $11°.4 = 140{,}000^{km}$ from the spot. The fact that the minimum distance of the western end always exceeded this quantity may account for its escape.

In view of the nature of the phenomena described in this paper, and the fact that evidences of whirls or radial structure have been shown, in connection with several different spots, on a large number of $H\alpha$ photographs, one is greatly tempted to enter at once into a discussion of the sun-spot theories of FAYE, REYE, EMDEN, HALM, ECKHOLM, BIGELOW, etc., all of which assume the existence of cyclones or vortices within the photosphere or the solar atmosphere. It is the part of prudence, however, to defer such discussion until our daily increasing supply of photographs is considerably enlarged. Moreover, I have devised improved methods for comparing photographs, which should facilitate the identification of objects for measurement, and experiments are also in progress with the purpose of bringing more clearly before the eye the nature of the changes which take place within the vortices. A simple kinetoscope has been advantageously used to observe the rapidly changing phenomena of June 3d, and more elaborate apparatus of this kind will soon be available

It may be well to direct attention, however, to certain points which have been noted:—

(1) In the series of photographs (on negatives Nos 4201 and 4202), which shows the large flocculus in the act of being drawn into the spots, the small flocculi near the spots remain almost unchanged in position, perhaps because of difference of level.

(2) Except in the case of the large flocculus, attempts to detect evidences of motion toward the spots have not yet proved successful, even along apparent lines of flow.

(3) Negative No. 4196, taken on June 2d, shows a dark comet-like object (apparently defining a line of flow) intersecting a bright eruptive flocculus. The appearance suggests that the eruption does not rise to the level of the vortex.

(4) Photographs of the $H\alpha$ line across bright flocculi, made in the second and third order spectra of the 30-foot tower spectrograph, indicate that this line has a complex structure which will require careful investigation.

(5) Since the velocity of the hydrogen drawn into the vortex is of the same order as that of eruptive prominences, distortions of the hydrogen lines at the limb may be due to the motion of this gas in vortices. If the line of sight were to pass through a vortex, distortions toward violet and red observed at the same point might result from motions of approach and recession on opposite sides of the vortex.

(6) The appearance of numerous hydrogen eruptions after the event of June 3d suggests that the hydrogen drawn down by the vortex subsequently rose to the surface in the neighborhood of the spots.

(7) In view of the fact that the distribution of the hydrogen flocculi frequently resembles that of iron filings in a magnetic field, it is interesting to recall the exact correspondence between the analytical relations developed in the theory of vortices and in the theory of electro-magnetism.[1]

(8) The gradual separation of the spots should not be overlooked.

Without entering at present into further details, a single suggestion relating to the possible existence of magnetic fields on the Sun may perhaps be offered. We know from the investigations of ROWLAND that the rapid revolution of electrically charged bodies will produce a magnetic field, in which the lines of force are at right angles to the plane of revolution. Corpuscles emitted by the photosphere may perhaps be drawn into vortices,[2] or a preponderance of positive or negative ions may result from some other cause. When observed along the lines of force, many of the lines in the spot spectrum should be double, if they are produced in a strong magnetic field. Double lines, which look like reversals, have recently been

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[1] See LAMB, "Hydrodynamics," third edition, p. 201.

[2] J. J. THOMSON, "Conduction of Electricity through Gases," p. 164.

photographed in spot spectra with the 30-foot spectrograph of the tower telescope,[1] confirming the visual observations of YOUNG and MITCHELL. It must be determined whether the components of these double lines are circularly polarized in opposite directions, or, if not, whether other less obvious indications of a magnetic field are present. I shall attempt the necessary observations as soon as a suitable spot appears on the Sun.

MT. WILSON SOLAR OBSERVATORY, June 20, 1908.

REMARKS ON THE PLATES.

As it seems to be impossible to obtain illustrations which accurately represent the original negatives, certain remarks regarding the plates are required.

Plate I. Both figures are fairly satisfactory, except that the limb of the Sun, in the lower right-hand corner, is not properly shown.

Plate II, Fig. 1. The position-angles of various points in the prominences are given in the text of the article. The faint parallel lines, which make an acute angle with the Sun's limb, are due to a slight irregularity in the motion of the spectroheliograph.

Plate II, Fig. 2. The black dots are defects produced in the sensitizing process.

Plate II, Fig. 3. The parallel lines are due to the cause mentioned above.

Plate III. This plate will serve to give a general idea of the appearance of the $H\alpha$ photograph of April 30th, but fails to show the flocculi in their proper intensity. Although many bright flocculi appear to be present, especially in the upper part of the image, the original negative actually shows very few of these objects, the most conspicuous ones being in the midst of the great storm area in the southern hemisphere. For details, see Plate IV. The parallel vertical bands are due to a periodic motion of the spectroheliograph.

Plate IV. As it was found by experiment that the flocculi on the photograph of April 30th are most accurately represented on a negative print, Plate IV is reproduced in this way. Thus the light objects on this plate represent the dark $H\alpha$ flocculi. The limb is not well reproduced and certain regions near the spots and in the lower part of the plate are too black.

Plate V. The scale is so small that this illustration serves merely to indicate the distribution of the sun-spots on April 30th, and the apparently insignificant nature of the group lying within the great storm area (near the center). The orientation is the same as for Plate III.

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[1] HALE. *Contributions from the Mount Wilson Solar Observatory*, No. 23; *Astrophysical Journal*, Vol. XXVII, p. 204, 1908.

Plate VI. This gives a fair idea of the appearance of the calcium (H_2) flocculi, though the limb is not well reproduced. The orientation is the same as for Plate III.

Plate VII, Fig. 1. The only bright flocculi that should appear in this figure are those in the neighborhood of the spot.

Plate VII, Fig. 2. The background comes out too bright, giving the appearance of bright flocculi in regions where they are not present. The only objects of this class shown by the original negative are very conspicuous in the figure.

Plate VIII, Fig. 1. This gives a fair idea of the original negative, the contrast of which is not very strong.

Plate VIII, Fig. 2. The contrast of the original is much stronger than in the case of Fig. 1, hence the bright flocculi near the spot are relatively too conspicuous. The background in the upper part of the figure is also too bright.

Plate IX, Fig. 1. The original is lacking in contrast. The region to the left of the spot should be much darker than it appears in the cut.

Plate IX, Fig. 2. This is a fairly satisfactory reproduction, though the bright flocculi should be somewhat stronger.

Plate X, Fig. 1. Except for a defect in the photograph, the bright flocculi surrounding the spot are fairly well shown. In other parts of the figure, however, the background comes out too bright.

Plate X, Fig. 2. This is a fairly satisfactory reproduction, though the background is too bright in various places.

SOLAR VORTICES AND THE ZEEMAN EFFECT.

By George E. Hale.

In a previous paper I have described and illustrated the vortices surrounding sun-spots recently photographed on Mt. Wilson with the Snow telescope and five-foot spectroheliograph.[1] While studying the vortices, it occurred to me that the rapid revolution of electrically charged particles in the solar atmosphere should produce a magnetic field within a sun-spot (Rowland effect), if a preponderance of negative or positive ions be assumed. Such a condition might result from the emission of corpuscles by the photosphere,[2] or, as Professor E. F. Nichols has suggested to me, from centrifu-

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[1] "Solar Vortices," *Contributions from the Mount Wilson Solar Observatory*, No. 26, *Publications A. S. P.*, No. 121.

[2] J. J. Thomson, "Conduction of Electricity through Gases," p. 164.

gal separation dependent upon differences in inertia between positive and negative ions. Light received from a spot (vortex) at the center of the Sun would then be parallel to the lines of force, and its spectrum should contain Zeeman doublets, having components circularly polarized in opposite directions. Close double lines, many of them previously observed visually in spot spectra by YOUNG and MITCHELL, had recently been photographed with the 30-foot spectrograph and tower telescope. I decided to determine whether such lines show characteristic evidences of polarization, and to search for other indications of the Zeeman effect.

I accordingly commenced work with the tower telescope and 30-foot spectrograph on June 24th. The only grating available for use with this instrument is a 4-inch Rowland, having 14,438 lines per inch, formerly used in the Kenwood spectroheliograph. Its ruled surface utilizes only a fraction of the light from the 6-inch collimator objective, but Seed "Gilt Edge" plates, sensitized by WALLACE'S process, gave fairly satisfactory spot spectra at λ 6200 (third order) in six minutes. A Fresnel rhomb and Nicol prism were mounted in front of the slit. Beside each spot spectrum the spectrum of the photosphere on either side of the spot, or at the center of the Sun, was photographed for comparison, the path of the light, through rhomb and Nicol, being the same for the spot and comparison spectra. On each plate the same region of the spectrum was photographed several times with the Nicol set at different angles, covering a range of about 90°.

The components of the true Zeeman doublet, observed under these conditions along the lines of force of a magnetic field, should change in relative intensity as the Nicol is rotated. When the spot was near the limb the results were uncertain, but when it reached a point about 45° from the center of the Sun the appearance of the doublets seemed clearly characteristic of the Zeeman effect, the relative intensities of the two components being reversed by rotating the Nicol.

More than thirty lines showed such an effect in the region λ 6230–λ 6241. In many cases these are not doublets, but there was a slight shift of the lines to the red and violet respectively, when the Nicol occupied two positions from 45° to 90° apart. This would appear to indicate that light from

the edges of these spot lines is circularly polarized in opposite directions. If so, the displacements are similar in character to those detected by ZEEMAN in his first observations of radiation in a magnetic field.

In order to determine whether the observed phenomena are to be regarded as true Zeeman effects, I have made a large number of photographs with the above-described apparatus, showing various regions of the spot spectrum from red to ultra-violet. These prove conclusively that the changes in relative intensity and position of the lines are due to the rotation of the Nicol. The results are consistent among themselves,—the Nicol in one position reducing the intensity of all the red components of doublets, while in the other position it reduces all the violet components.[1] Moreover, if the stronger component of a doublet appears, for example, on the red side, the single lines in the same spot spectrum are displaced toward the red, and *vice versa.*

As a great number of spot lines show these displacements, it is necessary to inquire whether they may result from unsymmetrical illumination of the grating, caused by rotation of the Nicol. This appeared improbable from the first, since the displacements were determined with respect to comparison spectra formed by solar light which passed through the rhomb and Nicol under precisely the same conditions as obtained in the case of the spot. An excellent test is afforded by many telluric lines in the red, which are not shifted by rotating the Nicol. The lines of the cyanogen fluting at λ 3883, photographed in the fourth order, also show no displacement.[2] It is well known that the lines of flutings are not affected in a magnetic field.

So far as I am aware, the only means of transforming a single line into a doublet, having components circularly polarized in opposite directions, is a strong magnetic field. It thus appears probable that a sun-spot contains such a field, which gives rise to doublets and to widened lines in the spot spectrum.

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[1] There may be a few exceptions to this rule, such as laboratory experience would lead us to expect.

[2] Three lines in this fluting, which I have measured on negative T 132, show a mean relative displacement of 0.0004 Angströms, corresponding to a rotation of the Nicol through 90°. This is much less than the displacement of the spot lines, and within the error of measurement.

It should be mentioned that few doublets appear on the plate in the blue and violet, while many conspicuous ones are found in the red. PRESTON and RUNGE have shown that for lines of a given spectral series the ratio $\frac{d\lambda}{\lambda^2}$ is a constant, but it is also true that wide doublets have been observed in the more refrangible region of metallic spectra. Why these do not appear in spots, if a magnetic field sufficiently powerful to produce red doublets is present, cannot now be answered.

The separation of the components of many doublets, as measured on the photographs, ranges from 0.018 to 0.216 Ångströms. All of these lines, and many of those which are merely shifted by rotation of the Nicol, will be studied in our laboratory with the aid of a large Du Bois magnet, which is fortunately available. In this work the Zeeman effect will be observed parallel and normal to the lines of force, and at certain intermediate angles, corresponding to various positions of spots on the Sun. It is interesting to note in this connection that lines which appear to be double in some of our spot photographs are triple in others. MITCHELL illustrates an excellent case of this sort (observed visually) in the *Astrophysical Journal,* Vol. XXIV, p. 79,[1] where a line which is double across the umbra and one side of the penumbra of a spot is triple across the opposite side of the penumbra. This may perhaps be due to the fact that the line of sight passed through an inclined vortex, parallel to the lines of force in one case and normal to them in the other.

These results suggest many possible subjects of investigation, some of which I am preparing to attack, in conjunction with our daily photographic observations of the solar vortices. The direction of the whirls, whether right-handed or left-handed, is a matter of prime interest now under examination.

The question naturally arises whether terrestrial magnetic storms, which are known to be closely related to sun-spots, can be caused, directly or indirectly, by solar magnetic fields. If the work now in progress should establish the existence of such fields, it would become necessary to make systematic records of their areas, intensities, and polarities, in all parts of the

[1] This paper contains many visual observations of the double lines in spot spectra.

Sun, for comparison with simultaneous records of terrestrial magnetism, before definite conclusions could be drawn.

If spots like those on the Sun are most numerous in the later stages of a star's development, it is conceivable that they may cover a large part of the disk of certain red stars. With sufficient dispersion it might therefore become possible to detect Zeeman doublets in the spectra of these objects. As a fixed spectrograph of great power is being provided for use with our 60-inch reflector, now nearing completion, I hope to make the necessary tests this autumn.

A more complete account of the sun-spot work, giving measures of the doublets and various other data, will soon be published in the *Astrophysical Journal.*

MT. WILSON SOLAR OBSERVATORY, July 3, 1908.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1908.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter	Sept. 3,	12^h	51^m	P.M.	First Quarter	Oct. 2,	10^h	14^m	P.M.
Full Moon	" 10,	4	23	A.M.	Full Moon	" 9,	1	3	P.M.
Last Quarter	" 17,	2	33	A.M.	Last Quarter	" 16,	7	35	P.M.
New Moon	" 25,	6	59	A.M.	New Moon	" 24,	10	47	P.M.

The autumnal equinox, the time when the Sun crosses the equator from north to south, and autumn begins, comes on September 23d, at 3^h A.M., Pacific time.

Mercury will not be in good position for observation during September and October. It passed superior conjunction on August 20th and became an evening star, but as its distance from the Sun increases its motion also carries it far to the south of the Sun, even more than is normal for eastern elongations in the autumn. It reaches greatest east elongation on October 4th. This distance, 25° 34′, is considerably greater than the average greatest elongation, but the planet is at this time more than 11° south of the Sun. So the planet does not remain above the horizon as much as an hour after sunset.

and there is little chance for naked-eye visibility. Within a week after the time of greatest east elongation *Mercury,* as seen from the Sun, reaches its most southern point, and this fact, as stated before, has a considerable effect in shortening the interval between the setting of the Sun and of the planet. At the time of greatest elongation the interval is almost always more than an hour, but at this time it is only about fifty minutes. After the time of greatest elongation the planet moves toward inferior conjunction, reaching it and becoming a morning star on October 28th.

Venus is a morning star, reaching greatest west elongation on September 14th. On September 1st it rises a little more than three and a half hours before sunrise, or a little before 2^h A.M. This interval increases about a quarter of an hour by the time of greatest elongation, and after that time it diminishes slowly, but up to October 31st is not less than three hours and one half. When *Venus* and *Mercury* reach their greatest west elongations in the autumn they are in favorable position for observation as morning stars, since they are then far to the north of the Sun and the interval between the rising of the Sun and of the planet is large. In like manner east elongations of these planets in the spring months give a good chance for observation as evening stars. *Venus* and *Jupiter* are in rather close conjunction on October 13th. The least distance between them is 36′, and *Venus* is south of *Jupiter.* Both planets are below our horizon at the time of closest approach, but the distance will not be greatly increased by the time they come into view on the morning of October 14th.

Mars passed conjunction with the Sun on August 21st and became a morning star, but does not move far enough away from the Sun to become visible in the morning twilight until October. At the end of October it rises about two hours before sunrise, and it may be seen without much difficulty in the morning twilight. As it is now only about as bright as the pole star, it can not be seen as near the Sun as *Mercury* can. *Mars* reaches its aphelion on September 3d, a few days after the time of greatest distance from the earth, but the distance from us does not vary much until after October 1st. Until then it remains about 248,000,000 miles. During October it

lessens by about 6,000,000 miles,—not enough to cause much increase in the brightness. *Mars* excites general attention only when near opposition. These oppositions occur about once in a little more than two years. But during all times, except for a month or so near the time of conjunction, the planet is in plain view and can be easily seen by any one who looks for it in the right place.

Jupiter passed conjunction with the Sun on August 17th and became a morning star. By September 1st it rises about half an hour before sunrise,—too short an interval for easy visibility, even though it is one of the brightest planets. It soon, however, draws away from the Sun far enough to be readily seen, and by October 1st it rises about 3^h A.M., and shortly after $1^h\ 30^m$ on October 31st. During the early days in September it is very close to the first-magnitude star *Regulus*, the brightest star in the constellation *Leo*. It is moving eastward and southward, covering about 12° during the two months' period.

Saturn comes to opposition with the Sun on September 29th, and is therefore above the horizon nearly the entire night throughout September and October, passing the meridian at about 2^h A.M. on September 1st, at about midnight on October 1st, and before 10^h P.M. on October 31st. It is moving westward in the constellation *Pisces*, about 4°, up to the end of October. The apparent breadth of the rings diminishes perceptibly the ratio of minor to major axis, changing from one eighth at the beginning of September to about one eleventh at the end of October. This diminution will soon cease, and the rings will broaden out again before the end of the year.

Uranus is in fair position for observation, passing the meridian at $8^h\ 15^m$ P.M. on September 1st, and at about $4^h\ 15^m$ P.M. on October 31st. It is nearly stationary in the constellation *Sagittarius*, a few degrees north of the easternmost star of the "milk-dipper" group. The nearest moderately bright star is π *Sagittarii* (a small fourth-magnitude), and the planet is about 1° west and 2° south of this star, in the direction of the bowl of the dipper.

Neptune rises shortly after 1^h A.M. on September 1st, and at about $9^h\ 15^m$ P.M. on October 31st. It is in the constellation *Gemini*.

NOTES FROM PACIFIC COAST OBSERVATORIES

THE RADIAL VELOCITY OF *α ORIONIS*

In view of the close connection between variations in the luminosity and in the radial velocities of stars, the disputed question of the variability of *α Orionis* suggested that it would be of interest to examine the radial velocities which have been found for this star. Five plates taken with the Mills spectrograph in its earlier form had given velocities in 1896-98 between +17.7 and +19.4^{km}. Before the autumn of 1907 three more plates had been obtained with the same instrument in its new form, and these had been only roughly measured. The result of more careful measurement and reduction was to make it practically certain that the velocity in 1906 January was 4 or 5^{km} in excess of the values previously found. When this was known Dr. CAMPBELL very kindly allowed spectrograms to be obtained on a large number of nights, and an even longer series of plates would have been secured had the weather not interfered. The plates from 5035F on have been only provisionally measured, but care has been taken not to introduce any systematic difference as compared with the earlier reductions, and the accuracy of the measures is sufficient for its purpose.

Two spectrograms of *α Orionis* had been obtained in 1903 by Professor W. H. WRIGHT while in charge of the Southern Mills Expedition. These plates he was good enough to measure for me, taking special care to make the reductions uniform with the system adopted by Dr. CAMPBELL for his earlier plates.

Dr. KUSTNER'S recent paper (*Astrophysical Journal*, **27**, 301) contains four results for *α Orionis* obtained in 1905-06. These may have a small systematic difference from the Mount

Hamilton results, and it seems likely from a superficial examination of the velocities of the few stars of this type contained in Dr. KÜSTNER's list that in fact the Bonn measures are about 2^{km} in excess of those secured on Mount Hamilton.

All the available results are collected in the table, an inspection of which can leave little doubt but that the radial velocity of *α Orionis* is variable. Generally speaking, the velocity seems to have tended towards a minimum about the year 1898 and to have reached a maximum about 1905 or 1906. In spite of the uncertainty as to any systematic correction which the Bonn results may require to make them comparable, they at least confirm the larger velocity derived from the only Mills plate obtained in 1906. From that date the velocity seems to have slowly decreased, without, however, falling to the level of the values which prevailed in 1896-98.

If the fact of the variable velocity be admitted, it is difficult to draw from the present data any certain conclusion as to the period and nature of the motion. The general variation indicated is one of long period, certainly of many years. But there are indications of irregularities of shorter period about which it is hard to decide whether they are real or spurious. The results obtained in the last two months of 1907 suggest a fairly continuous decrease of the velocity of about 2^{km}. On the other hand, the fourteen plates obtained between 1908 January 5 and April 19 all fall within a range of 1.2^{km}, which, in view of the expeditious method of reduction adopted, must be considered a very satisfactory representation of uniform motion. On the whole, the star seems to deserve continued and careful attention.

Under the circumstances, *α Orionis* is not a suitable star for use in a determination of the Solar Parallax. It is included in the working list of the Cape Observatory (*Astrophysical Journal*, **27**, 165).

H. C. PLUMMER.

1908 July.

Plate.	Date.	Vel.	Red. by	Spectrograph.
176 B	1896 Oct. 3	+ 19.4	CAMPBELL	First Mills
225 A	Dec. 8	+ 18.5	"	"
243 D	1897 Jan. 5	+ 17.8	BURNS	"
610 A	1898 Jan. 25	+ 18.4	CAMPBELL	"
644 A	Feb. 14	+ 17.7	"	"

Plate.	Date	Vel.	Red. by	Spectrograph.
3063 D	1903 Dec. 1	+ 19.36	H. C. P.	Second Mills
3078 F	7	+ 18.42	"	"
4160 B	1906 Jan. 26	+ 23.97	"	"
5018 D	1907 Nov. 1	+ 22.56	"	"
5019 E	1	+ 22.74	"	"
5029 D	7	+ 23.45	"	"
5035 F	10	+ 21.9	"	"
5046 D	15	+ 22.0	"	"
5047 A	21	+ 21.4	"	"
5051 B	23	+ 21.2	"	"
5052 D	23	+ 20.4	"	"
5057 H	24	+ 21.7	"	"
5065 H	26	+ 22.8	"	"
5071 D	29	+ 20.1	"	"
5073 A	30	+ 20.3	"	"
5078 B	Dec. 17	+ 19.1	"	"
5084 C	23	+ 20.9	"	"
5089 C	1908 Jan. 2	+ 19.2	"	"
5096 D	5	+ 21.1	"	"
5097 H	5	+ 20.7	"	"
5111 C	9	+ 21.9	"	"
5118 A	28	+ 20.7	"	"
5138 B	Feb. 17	+ 21.4	"	"
5205 A	Apr. 1	+ 20.7	"	"
5207 A	2	+ 20.9	"	"
5218 H	6	+ 20.9	"	"
5219 A	8	+ 21.2	"	"
5224 B	9	+ 21.6	"	"
5227 E	12	+ 21.0	"	"
5228 A	16	+ 21.0	"	"
5234 A	17	+ 21.9	"	"
5236 A	19	+ 20.8	"	"
(4 III)	1903 Sept. 15	+ 20.72	WRIGHT	Southern Mills
(42 III)	Nov. 11	+ 20.32	"	"
(356)	1905 Feb. 9	+ 27.89	ZURHELLEN	Bonn
(367)	Mar. 1	+ 25.30	"	"
(533)	Dec. 30	+ 26.46	"	"
(591)	1906 Mar. 4	+ 26.64	"	"

A DISTURBED REGION IN THE CORONA OF JANUARY 3, 1908.

In his study of the solar corona of April, 1893, as photographed by the Phoebe A. Hearst Expedition from the Lick Observatory to Chile, Professor SCHAEBERLE was led to the conclusion that the inner ends of the coronal streamers coincide in position with disturbed areas in the photosphere of the Sun. Tracing the streamers inward to the Sun's surface he located six chief centers of origin. On comparing these results, obtained from the coronal image alone, with the photographic record of the uneclipsed Sun made by Professor HALE in Chicago on the day of the eclipse, Professor SCHAEBERLE noted an agreement between the points determined by him and the disturbed areas shown on the photograph of the uneclipsed Sun. From a study of his and previous coronal photographs he concluded that the origins of the coronal streamers are, in the main, confined to the spot-zone regions. [See *Contributions from the Lick Observatory*, No. 4, pp. 108-113.]

In *Lick Observatory Bulletin*, Nos. 9 and 18, Dr. PERRINE, in charge of the Crocker Eclipse Expedition to Sumatra in 1901, described an area [in space a volume] of unusual disturbance recorded on his photographs of the corona. A number of streamers appeared to radiate from a common point, situated behind the Moon, as if thrown out by an explosion at the point, though it was not contended or suggested that an explosion had actually occurred. On comparing the estimated position of the invisible vertex with photographs of the uneclipsed Sun obtained at Dehra Dun, India, on the day of the eclipse and on several days preceding and following the eclipse, it was found that the apex of the disturbance was apparently coincident with the large and only sun-spot shown on the entire series of Sun photographs. It was impossible to doubt that the coronal disturbance was intimately connected with the sun-spot.

The large-scale photographs of the corona of August 30, 1905, secured by the Crocker Expeditions to Spain and Egypt likewise showed an extensive region in the southeast quadrant composed of prominent streamers which appear to radiate from a common point. The apex of the cone of disturbance

projected upon the photographic plate is some distance within the Sun's limb. The apex was, no doubt, near the photosphere.

The estimated position of the vertex on this occasion fell fairly near, but not in coincidence with, a prominent sun-spot shown on photographs taken at Mt. Hamilton on the day of the eclipse. Tracing the position of the spot back through one revolution of the Sun, it was found that the sun-spot was on August 3d in the estimated position of the vertex. Just what weight should be given to this observation, as related to the question of a close connection between coronal structure and sun-spots, is uncertain. The detailed measurements are published in *Lick Observatory Bulletin*, No. 115.

Lick Observatory Bulletin, No. 131, which was sent to the printer several months ago and is now ready for mailing, describes briefly a similar cone of disturbance in the corona observed by us on the Flint Island photographs of January 3, 1908. Recent careful measures of the position of the vertex place it at

Position angle,	75°.0 E. of N.
Distance from Sun's center,	13′.7

It should be said that the disturbance, while on a very large scale, does not fix the position of the vertex so definitely as in the case of the 1901 disturbance, as the streamers seem to radiate from a small area or perhaps from several points near each other.

The photoheliograph camera of the Lick Observatory was dismounted in the fall of 1907 to make way for the new fire-proof building, and photographs of the Sun at and near the time of the eclipse could not be secured here. At our request, Director HALE of the Mt. Wilson Solar Observatory most kindly supplied the deficiency by loaning photographs of the uneclipsed Sun taken on January 3, 4, and 5, 1908. There was a region of great apparent disturbance near the east limb, in north latitude 10° ±, shown especially well on a spectroheliograph H_1 negative. This region contains five or more sun-spots within a few degrees of each other. From the position of the Sun's equator marked on the back of the photograph by Professor HALE, combined with the angle between the equator and the east and west line, we have measured the

positions of the chief spots of the group for the time of total eclipse, referred to the Sun's center, as follows:—

Position Angles.	Distance.
71°.8 E. of N.	13'.4
77 .9	13 .2
77 .5	14 .8
80 .5	14 .2
82 .0	14 .8

The estimated position of the vertex falls within the spot group; and it is scarcely possible to doubt that the disturbance in or near the photosphere is intimately related to the disturbed conical volume of the corona. Whether the coronal and photospheric disturbances are related to each other as cause and effect, or, more probably, as joint effects of a more general cause, is not known.

The subject takes on renewed interest in view of Professor HALE's recent discovery of cyclonic motion or vortices in sunspots and surrounding regions.

W. W. CAMPBELL,
S. ALBRECHT.

1908 July 31.

FLINT ISLAND CORONA.

In No. 119 of these *Publications* appeared half-tone illustrations of the solar corona from photographs made by the Crocker Expedition to Flint Island.

In No. 120 I called attention to the fact that the prints supplied by an Eastern engraver and printer were inferior to the proof-sheets of the illustrations, and that the printer had made an error in orienting the smaller coronal subject. In view of these facts, acknowledged by the engraver, new prints of the two subjects have been supplied by him. They are distributed with the present copy, No. 121. It is advised that members insert them in No. 119 to replace the poorer prints.

There is perhaps no astronomical subject more difficult to reproduce by mechanical process than the solar corona, and it is necessary to recognize that in the best half-tone reproductions the delicate details of structure and the minute differences of intensity are almost wholly lost. In view of the

great injustice done to the merits of the original negatives and the correspondingly erroneous impressions conveyed by the prints on paper, it is a question whether an attempt to publish the coronal photographs by such methods is not a mistake. Every one who proposes to make a careful study of coronal subjects must depend upon the original negatives or copies on glass made from them.

W. W. CAMPBELL.

THE PARTIAL SOLAR ECLIPSE OF JUNE 28, 1908.

The beginning and ending of the eclipse were observed with the 36-inch refractor. The object-glass was capped down to eight inches in diameter, and a neutral-tinted glass covered the eye-piece. The times of apparent contact of Sun and Moon were noted, as follows:—

Beginning..	$6^h\,20^m\,39^s$ A.M.,	Pacific	Standard	Time.
Ending.....	8 6 13 A.M.,	"	"	"

It is well known that the estimated time of beginning of eclipse is especially subject to error, for the reason that the observer does not see the Moon's approach, but is suddenly made aware that the Moon has entered upon the Sun's image.

Special but unsuccessful efforts were made to see the Moon's limb extending outside of the Sun's image: only that part of the Moon's limb projected on the Sun was visible. Dr. ALBRECHT also observed the Moon's limb immediately following the beginning of the eclipse, but could not trace it beyond the Sun's edge. He assisted in all the above observations.

The observations were all made through thin clouds. The beginning occurred with the Sun low in the sky and the seeing rated as I on a scale of V (perfect). The end occurred with seeing II.

W. W. CAMPBELL.

June 29, 1908.

OBSERVATIONS OF THE PARTIAL ECLIPSE OF THE SUN JUNE 28, 1908.

The various phases of this eclipse were observed with the object of seeing whether or not the dark body of the Moon could be seen projected against the inner, and very bright, parts of the corona.

The observations were made with the 12-inch equatorial, stopped down to three inches, using powers of about 125 and 175. A diagonal, plane-glass reflector was used in front of the eye-piece, and as light a shade-glass as possible.

Thin clouds covered the sky during the observations, but were not sufficiently dense to interfere with seeing the detail of structure in spots.

No evidences, whatever, of the corona were seen.

The contacts were observed as follows:—

First Contact, 1908, June 28.. $2^h\ 20^m\ 39^s$ G. M. T.
Last contact, 1908, June 28.. 4 6 16 "

It was estimated that geometrical first contact occurred two seconds earlier than the above time, which is the time when the contact was certain. The time of the last contact observation is that of the disappearance of the lunar limb, which is practically that of geometrical contact.

A high, gusty wind blew from the north during the observations, weakening somewhat toward the end. The seeing was extremely bad during the early part of the observations, but improved very much before last contact.

C. D. PERRINE.

MT. HAMILTON, CAL., June 29, 1908.

THE ORBITS OF THE SPECTROSCOPIC BINARIES β *HERCULIS* AND *o LEONIS.*

β *Herculis.*—This star was found to have a variable radial velocity by Dr. CAMPBELL in 1899. By September, 1902, a series of thirty-two spectrograms had been obtained at Mt. Hamilton, and a determination of the orbit from this material was undertaken by Dr. H. M. REESE. Before his investigation was quite completed, however, he resigned his position in the Lick Observatory, and left in June, 1903, without preparing his results for publication.

A careful examination of the papers left by Dr. REESE showed that his work had been carried to an advanced stage, and that little was necessary to put it in a final form and to verify that it represented the orbit with satisfactory accuracy at the time when the observations were made. A set of provisional elements had been adopted after some trials, and from the equations of conditions based on these elements differen-

tial corrections had been calculated in the usual manner by the method of least-squares. The result of applying these is to give the following final system:—

ELEMENTS OF β *HERCULIS.*

Period, $U = 410.575$ days; $\mu = 2\pi U^{-1} = 0.0153034$

$T =$ J. D. 2415500.374 = 1901, April 25, 9^h, G.M.T.

$e = 0.5498$; $\phi = 33° \; 21'$

$\omega = 24° \; 36'.3$

Velocity of system, $\gamma = -25.52^{km}$

$K = 12.782^{km}$; $V = -19.13 + 12.782 \cos u$

which represent the observations satisfactorily. From them may be deduced

$$a \sin i = 60{,}280{,}000^{km}$$

$$(m + m') \sin^3 i = 0.0519 \, (1 + m/m')^3$$

where m is the mass of the star whose spectrum has been observed and m' the mass of the other star, the Sun's mass being unity.

o Leonis.—The variability in the velocity of this star was discovered by Dr. CAMPBELL in 1898. Its spectrum had previously been described as of composite type by Miss MAURY. It is interesting to notice that out of a list of eighteen stars so described by her, eight have now been found to possess a variable velocity in the line of sight. Lines of the second spectrum can be recognized and measured separately on the plates except when the radial velocities of the components are in the neighborhood of the velocity of the system.

A series of thirty-eight plates had been secured in 1898-1900, and three were taken in the present year with the object of improving the period. The eccentricity of the orbit is certainly very small, and a circular orbit has been adopted. The separation of the two spectra makes it possible to determine the ratio of the masses. The results are as follows:—

Period = 14.4980 days

Ratio of masses, $m_1 : m_2 = 7 : 6$

$V_1 = +27.07 + 54.05 \sin \mu \, (t - T)$

$V_2 = +27.07 - 63.06 \sin \mu \, (t - T)$

$T =$ 1899, Jan. 1.477; $\mu = 24°.831$

$a_1 \sin i = 10{,}775{,}000^{km}$, $m_1 \sin^3 i = 1.302$

$a_2 \sin i = 12{,}571{,}000^{km}$, $m_2 \sin^3 i = 1.116$

The comparison of the observations with the results of calculation from these figures shows great irregularities in the measures. The measures can be arranged in order of increasing inaccuracy thus: (1) the measures of component I when II is separately visible, (2) the corresponding measures of component II, (3) the measures of I when II is not separated. Of (1) it may be said that the results are distinctly poor and fall below what is to be expected from a careful measurement of a large number of lines in a single spectrum. The lines of II which can be clearly distinguished on any one plate are few (sometimes no more than two), and comparisons in the second group shows differences which, taken on the whole, must be considered satisfactory under the circumstances. But in the third group the interference between the two superposed spectra has disastrous effects on the accuracy. In view of the fact that spectrum II separately is quite inconspicuous in comparison with I, this is rather surprising, but that the interference of the spectra is the effective cause is clear because the large displacements are all in the direction of the mean velocity of the system. Thus one plate which shows the largest discrepancy gives a measure $+ 28^{km}$, when it should give $+ 38^{km}$, for component I. In cases like the one alluded to, the superposition of the two spectra does not affect the appearance of the lines noticeably, although the inconsistency of the individual lines becomes apparent in the measures. It has not proved possible to isolate lines of the first spectrum which are unaffected by the second.

A comparison of the above results has been made with a series of twelve plates obtained in 1905-1906 with the Bonn spectrograph, and discussed by Dr. ZURHELLEN (*Astronomische Nachrichten,* No. 4151). The star is not a suitable one for instituting a comparison, for reasons explained, but there seems to be a satisfactory absence of systematic difference between the Bonn and Mt. Hamilton observations.

May, 1908. H. C. PLUMMER.

Discovery of Many Small Nebulæ Near Some of the Globular Star Clusters.

Heretofore but few nebulæ have been known to exist near the globular clusters. It has been pointed out that nearly half of the globular clusters lie in or very near the Milky Way, a region almost devoid of the small, "unresolved" nebulæ which have been found so plentifully in non-galactic regions of the sky.

Association with Keeler's Crossley photographs led to a suspicion that the regions about these clusters were, on the whole, non-nebulous regions. Just recently, however, quite contrary facts have developed.

Upon repeating observations of some of these clusters under the greatly improved conditions now provided by the new mounting for the Crossley mirror, I was struck with the large number of small nebulæ on some of the plates. Thus far three of these subjects have been repeated under the improved conditions, viz:—

N. G. C. 7078 (*M* 15 *Pegasi*)......	16	nebulæ	recorded.
N. G. C. 7089 (*M* 2 *Aquarii*).....	30	"	"
N. G. C. 7099 (*M* 30 *Capricorni*)...	31	"	"

The star images on these plates are so sharply defined that it is possible to distinguish the very minute nebulæ with ease. On the earlier plates but few of them can be distinguished from the stars, owing to the fuzziness of all of the images. The great majority of these nebulæ are little or no larger than an out-of-focus distorted star image.

In the course of a study of the globular clusters I have obtained photographs of the majority of these objects within reach of the Crossley reflector. They were obtained with the old mounting and in the experimental stages of the new one. The images are generally poor, but I have examined them for nebulæ. On three negatives I have found eight, fifteen, and thirty-two respectively. On several others I have found from one to four.

Some nebulæ were suspected on nearly all of the remaining negatives, but the images are too poor to decide. They appear to be most numerous about clusters which are farthest from the galaxy. In a few instances, nebulæ were found in the edges of the clusters.

Practically all of the small nebulæ found about the globular clusters are elliptical or circular. Those large enough to show structure are spirals. Doubtless the majority of them are spirals.

C. D. Perrine.

Mt. Hamilton, Cal., July 16, 1908.

The Difference of Longitude between Lick Observatory and Mare Island Observatory.

At the request of the Bureau of Equipment, Navy Department, Washington, D. C., the Lick Observatory recently determined the difference of longitude between it and the U. S. Observatory at Mare Island. The results have been forwarded to the above Bureau and also published in *Lick Observatory Bulletin,* No. 130, vol. IV.

The observations for clock errors and rates at the two stations were carried out by Professor R. H. Tucker and Mr. R. F. Sanford. Each observed two nights at each station.

For time observations the Repsold Meridian Circle of the Lick Observatory was used on Mount Hamilton, while the Stackpole Broken Transit No. 1502 of 2.5 inches aperture was used at Mare Island.

The mean of the observed differences of longitude between the two stations when corrected for systematic errors is $2^m\ 30^s.74$, with a probable error of $\pm\ 0^s.01$. The value of the longitude of the Meridian Circle of the Lick Observatory adopted is that determined by the U. S. Coast and Geodetic Survey in 1888 and published in the report of 1889 as Appendix No. 8. This value is $8^h\ 6^m\ 34^s.81$* west of Greenwich. The resulting longitude of Stackpole Transit No. 1502 at Mare Island is therefore $8^h\ 9^m\ 5^s.55$ west of Greenwich.

Mt. Hamilton, May 12, 1908.

R. F. Sanford.

* The Superintendent of the U. S. Coast and Geodetic Survey, Washington, D. C., has recently called my attention to a later readjustment of longitude within the United States, as a result of which the longitude of the Lick Observatory is assigned the value of 8h 6m $34^s.89$. The corresponding longitude of the Mare Island Observatory becomes 8h 9m $5^s.63$. W. W. C.

A New Photographic Plate.

Recently a series of tests has been made here to determine the speed of the new "Sigma" plate made by the Lumière North American Company, Ltd., of Burlington, Vermont. The comparison was made by exposure times between the Lumière plate and the fastest plates heretofore on the market. A series of exposures on the sky was made with a one-prism spectrograph attached to the 36-inch refractor. The plates were then developed until chemical fog began to appear, with the following developer*:—

A	*B*
Water, 900cc	Water, 900cc
Oxalic acid, 1 gram	Lumière's formosulphite, 120 grams
Pyro, 30 grams	

Using 1 part of A, 1 part of B, 2 parts of water.

Designating the Lumière plates by L and the others by X, we have the following list, arranged in order of density of spectrum, braces connecting those nearly equivalent:—

$$\begin{cases} X & 5^s \\ L & 2 \end{cases} \qquad \begin{cases} X & 20^s \\ L & 10 \end{cases}$$

$$\begin{cases} X & 10^s \\ L & 5 \end{cases} \qquad \begin{cases} X & 30^s \\ L & 15 \end{cases}$$

$$\begin{cases} X & 15^s \\ L & 8 \end{cases}$$

This test appears to confirm the makers' claim that the new plate is twice as fast as any other plates on the market.

The grain of the Lumière plate is somewhat larger than that of other fast plates, but this will be no material disadvantage for purposes where speed is the first consideration.

The color curve is about the same as for other fast plates of standard American makes.

E. A. Fath.

Lick Observatory, July 23, 1908.

* This developer gives better results than either hydrochinone or dianol.

Personals.

The superintendency of the observing station of the Carnegie Institution Expedition to the Argentine Republic having been offered to Astronomer Tucker, the Regents of the University of California were pleased to grant him a three years' leave of absence in order that he might accept the appointment. It is understood that Director Boss of the Dudley Observatory, Albany, who is in charge of the Southern Hemisphere work of the Carnegie Institution, accompanied by Professor Tucker, will sail from New York in August.

Mr. William H. Wright, Assistant Astronomer in the Lick Observatory from 1897 to 1903 and from 1906 to 1908, and Acting Astronomer in charge of the D. O. Mills Expedition to Chile from 1903 to 1906, has been promoted to the position of Astronomer in the Lick Observatory.

Dr. Sebastian Albrecht, a Fellow in the Lick Observatory during the years 1903-1906, and Carnegie Assistant in the years 1906-1908, has been promoted to the position of Assistant Astronomer in the Lick Observatory.

Mr. R. F. Sanford, for two years past Carnegie Institution assistant in the Lick Observatory, has been appointed by Professor Boss to act as an assistant to Professor Tucker in the Argentine Republic.

Miss A. Estelle Glancy, of the Class 1905, Wellesley College, and for the past two years an assistant in the Students' Observatory at Berkeley, has been appointed Fellow in the Lick Observatory.

W. W. Campbell.

GENERAL NOTES.

Vacation Pastimes.—Authors do not always realize that a great deal of time might be saved to those who use their books if they would give accurate and exact information concerning the works to which they make reference. I have recently had occasion to use Professor NEWCOMB's work on the Precessional Constant.* In this memoir the author refers a number of times to his own work, "Elements and Constants," but at no place in the memoir, so far as I am able to find, does he give an exact reference which would enable one not familiar with the work to readily obtain it. Now possibly anyone who makes pretense to being an astronomer ought to be ashamed to admit that he is not familiar with this work, but I am obliged to make this ignoble confession. Having learned of its existence, however, I became possessed of a strong desire to see the book. The card index of the University library threw no light upon the subject. As many of Professor NEWCOMB's most valuable contributions to astronomical science have been published in the *Astronomical Papers of the American Ephemeris and Nautical Almanac,* the next thought was to look through them, but the examination revealed nothing. (Some of the parts of the later volumes are unfortunately missing.) The next thought was to examine NEWCOMB's "Compendium of Spherical Astronomy," recently published by The Macmillan Company. One of the special, and also one of the most valuable, features of this book is the notes and references given at the end of the various chapters. So far as I have examined them these references seem to be correct and exact, except the references to the author's own "Elements and Constants." At no place apparently does he give an exact reference to it. On page 231 of the "Compendium," under the subject of precession and nutation, we find a small table of numerical

* *Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac,* vol. VIII, part I. Washington, Bureau of Equipment, Navy Department.

quantities and a footnote, as follows: "*Astronomical Papers of the American Ephemeris,* vol. IV; 'Elements and Constants,' p. 186." Now *Astronomical Papers,* vol. IV, contains HILL's "Theory of *Jupiter* and *Saturn,*" and has nothing whatever to do with precession and nutation. "'Elements and Constants,' p. 186," is very illuminating. On page 249 "Elements and Constants" is again referred to in this abbreviated way in two footnotes, while OPPOLZER's classic work is referred to in detail, even to the date of publication. On page 255 we find a reference, "'The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy,' published by the *American Nautical Almanac* in 1895," which is presumably the full title of "Elements and Constants," but still gives no information as to whether it was published as one of the *Astronomical Papers* or in the numbers of the *American Ephemeris and Nautical Almanac,* or otherwise. Further examination of the series of publications just mentioned revealed nothing. Still further search, however, brought a happy result. In *Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac,* vol. VI, part II (Tables of *Mercury*), page 1, we find, "The elements of *Mercury* on which these tables are based are found in the author's work entitled. 'The Elements of the Four Inner Planets, and the Fundamental Constants of Astronomy,' forming a supplement to the *American Ephemeris and Nautical Almanac* for the year 1897, pp. 181-185," which gives the information which ought to have been given at a number of places where it was not. It is indeed a delightful pastime to spend one's vacation in work of search and research(?) of this kind.

S. D. T.

Notes from "Science."—Dr. JOHANN GOTTFRIED GALLE, from 1851 to 1895, professor of astronomy and director of the observatory at Breslau, has celebrated his ninety-sixth birthday.

At the University of Indiana W. A. COGSHALL has been promoted from assistant professor to associate professor of astronomy.

Professor H. H. TURNER, F.R.S., has been elected correspondent of the Paris Academy of Sciences in the section of astronomy.

At Princeton University HENRY NORRIS RUSSELL and RAYMOND SMITH DUGAN have been made assistant professors of astronomy.

Sir GEORGE DARWIN, K.C.B., F.R.S., has been elected a foreign member of the Amsterdam Academy of Sciences.

The astronomical observatory and library founded in honor of MARIA MITCHELL, adjacent to her birthplace, on Nantucket, were formally dedicated on July 15th.

Professor A. O. LEUSCHNER, Director of the Students' Observatory of the University of California, who has been granted a year's leave of absence, left for the East in June. Most of the year will be spent in Berlin and Paris. During Dr. LEUSCHNER's absence the Students' Observatory will be in charge of Assistant Professor R. T. CRAWFORD as acting director.

Comet *Encke* was rediscovered May 27th, a month after perihelion passage, by WOODGATE at the Cape of Good Hope. The cometary objects photographed last December and January at Heidelberg, and at first announced as ENCKE's comet, are now thought to be fragments of it.—*Journal B. A. A.*

A fourth member of the TG or *Achilles* group of asteroids was recently announced. It is CS, discovered March 25th at Heidelberg, and will probably soon be known by a Homeric name, along with *Achilles, Patroclus,* and *Hector.* Special interest attaches to this group because of their approach to the conditions of the equilateral triangle solution in a system of three finite bodies. Each of them moves approximately in a vertex of an equilateral triangle that it forms with *Jupiter* and the Sun.

J. D. M.

In *Astronomische Nachrichten,* No. 4249, PAUL GUTHNICK finds that the variation of brightness of *Eros* depends on the phase-angle. *Eros* presents a greater range of phase than the normal asteroid because of the nearer approach of its orbit to the orbit of the Earth. It is also bright enough for measurement with ordinarily powerful photometric apparatus. The difficulty of connecting *Eros's* variation with change of phase augurs little success for similar research with the average asteroid. Taking SVEDSTRUP's mean distance of the "mean asteroid" as 2.65 astronomical units, computation shows its change of magnitude due to phase to be only about $0^m.04$. Even from *Mars* the change is only $0^m.10$.

J. D. M.

M. NORDMANN, of Paris, finds that violet light (wave-length 4300) arrives from *Algol* sixteen minutes later than red light (6800). In the case of λ *Tauri* the delay is three times as great. M. TIKHOFF, of Pulkowa, finds that violet light (4300) from RT *Persei* reaches us four minutes later than yellow light (5600); and that ultra-violet light (4000?) from W *Ursæ Majoris* follows orange light (6100?) by ten minutes. In 1903, M. BÉLOPOLSKY found that the orbit of β *Aurigæ* derived spectroscopically from indigo light (4500?) was in advance of the orbit from violet light. In each case, the retardation is greater for shorter waves. Its smallness leads Mr. GAVIN J. BURNS, writing in *Journal B. A. A.*, **18**, 328, 1908, to attribute it to an extensive atmosphere surrounding the star rather than to a resisting medium filling interstellar space. If due to the latter, we shall probably be able to translate retardation into distance in the case of stars of rapid light change. At present, *Algol* seems to be the only variable star whose parallax has been determined.

Meanwhile, Dr. SCHLESINGER[1] finds that *Algol's* eclipse is reported about two hours *earlier* by radial velocity determinations in ultra-violet light of wave-length 4200, than by visual observations (of average wave-length 5700 perhaps); and a similar lag exists in BÉLOPOLSKY'S[2] elements of this star. These results evidently demand a different explanation. None has yet been offered.

J. D. M.

[1] *Publications of the Allegheny Observatory*, **1**, 32, 1908.

[2] *Mitteilungen der Pulkowa Sternwarte*, **1**, 103, 1906.

The attention of members of the Society is called to the fact that the notice printed on the last page of the *Publications* has been revised.

Royal Observatory, Greenwich.—The annual visitation of the Royal Observatory took place June 4th, the Board of visitors being constituted as follows: Lord RAYLEIGH, Mr. H. F. NEWALL, Professor W. G. ADAMS, Professor J. LARMOR, Professor Sir J. NORMAN LOCKYER, Lord ROSSE, Principal Sir A. W. RÜCKER, Captain Sir W. DE W. ABNEY, Professor Sir R. S. BALL, Professor R. B. CLIFTON, Dr. J. W. L. GLAISHER, Sir W. HUGGINS, Mr. E. B. KNOBEL, Professor H. H. TURNER, Professor Sir G. H. DARWIN, Rear-Admiral A. MOSTYN FIELD (Hydrographer of the Navy), and Mr. W. D. BARBER (secretary). A large number of gentlemen interested in astronomy were present by invitation of the Astronomer Royal, and took part in the inspection of the observatory and instruments.

The Astronomer Royal presented his report, which deals with the work of the observatory during the past year. . . . It was discovered last year that the method of illuminating the field of the transit-circle by means of an elliptical annular reflector, lit by an axis lamp, was open to objection, as the tilting of the reflector to different points to produce various degrees of illumination caused a shift in the center of light, and an apparent shift in the wires; it is possible that part of the "magnitude equation" of faint stars arises from this cause. A uniform central illumination has now been substituted, a small elliptical reflector with a matt white surface being cemented to the center of the object-glass, reflecting the light of a small electric lamp; change in the degree of light is produced by altering the current through the lamp by a rheostat. This plan has been in use in the Altazimuth for a year with very satisfactory results; arrangements have been made on each instrument to take a few transits by the old method for the purpose of comparison. A new arrangement of wires has also been inserted in the collimators of the transit-circle, thin parallel wires replacing the thick oblique wires in former use. . . .

The 28-inch refractor has been used for the observation of double stars; 81 were observed with a distance of less than ½″, 95 between ½″ and 1″, 101 between 1″ and 2″, 211 over 2″. Among these *κ Pegasi* was observed on fifteen nights, *δ Equulei* on thirteen, and 70 *Ophiuchi* on sixteen. Mr. BOWYER is taking a special course of observations of this last star, with a view to settling the question of the inequalities in its motion. Observations of the diameters of *Jupiter* and his satellites have also been made with the 28-inch. With the 26-inch photographic refractor thirty-one photographs of *Neptune* and his satellites have been obtained; while with the 30-inch reflector *Phœbe* (the ninth satellite of *Saturn*) has been photographed on sixteen nights, *Jupiter VI* on thirty nights, *Jupiter VII* on twenty-one nights, *Jupiter VIII* on twelve nights, also fifty-four minor planets on 140 nights, Comet *d* 1907 (DANIEL) on thirteen nights, Comet *e* 1907 on eight nights. *Phœbe* is an excessively faint object of the 17th magnitude, discovered by Professor W. H. PICKERING in 1898, but it was not till last year that *Saturn* had come far enough north to permit the satellite to be photographed at Greenwich. These photographs will be of great use for giving an improved value of the mass of *Saturn*, which is uncertain to a small extent.

THE EIGHTH SATELLITE OF *JUPITER*.

The eighth satellite of *Jupiter* is a new discovery, made at the Royal Observatory by Mr. MELOTTE. Examining a photograph of the sixth and seventh satellites, taken at the end of February, he found an unknown moving body on the plate; looking back, he detected it on eight other plates taken during the preceding month. Since then exposures have been made on every fine night when the Moon was absent, but it has only been possible to photograph the object on four more nights, the last being on April 24th. In addition, it has been observed by Dr. WOLF at Heidelberg, and at the Lick Observatory. It appears to be a very distant satellite, at a distance of some sixteen million miles from *Jupiter*, and with an orbit inclined some 30° to his. Its period of revolution would thus be two years, its distance from the planet being two and one-half times that of the sixth and seventh satellites and 160

times that of the fifth satellite, which is the nearest to *Jupiter*, so that the range of distances in the Jovian family is much greater than in the Sun's family of planets. A further point of interest in the new satellite is that it appears to revolve around *Jupiter* in a retrograde direction, in opposition to all the other members of the family. In this point it resembles *Phœbe*, the outermost member of *Saturn's* family; Professor PICKERING suggests that the primitive rotation of the planet was retrograde, and that it was subsequently reversed by the action of solar tides; these distant satellites are supposed to have been born before the reversal, so that they are a relic of the primitive order. The new satellite is of the sixteenth magnitude, implying a real diameter of about thirty-five miles. Even as seen from the surface of *Jupiter* it would only be of the eighth magnitude, and so would be utterly invisible to the naked eye.

COMETS.

DANIEL'S comet was a very conspicuous object in the morning sky last August, probably brighter than any seen in these latitudes since 1882, and the photographs taken of it show a great amount of interesting detail. The tail was fan-shaped, and composed of a number of nearly straight jets diverging from the nucleus. This type has been exhibited by many recent comets. According to Professor BREDICHIN'S theory, the different jets have different specific gravities, and so are expelled from the nucleus with different velocities. Several plates were exposed last winter in the search for HALLEY'S comet, but without success. It is rather unfortunate that the region of search was in the Milky Way, between *Gemini* and *Monoceros*, and consequently the background is extremely richly strewn with faint stars, which makes the task of picking up an exceedingly faint object like the comet much more difficult. Next autumn the search will be resumed, with more prospect of success, as the comet will then be only slightly outside the orbit of *Jupiter*, and many comets have been followed to a greater distance than that. A large amount of computational work on this comet has been carried out by Messrs. COWELL and CROMMELIN. It consists of two parts—(1) to ascertain as accurately as possible the circumstances of

the next return; (2) to carry back the perturbations as far as possible in order to test the accuracy of Dr. HIND's identifications in a paper he presented to the Royal Astronomical Society some fifty years ago. They find that the probable date of the next return is 1910, April 8, which is six weeks earlier than that given by DE PONTÉCOULANT. Unfortunately, the new date means a less fine display in these latitudes, for, though the comet will make a near approach to the earth on 1910, May 10, it will then be some 20° south of the Sun, and so will set very soon after him. The conditions in the Southern Hemisphere will be much more favorable. The other research has been carried back to the year A. D. 760, and on the whole Dr. HIND's results are confirmed, though he is shown to be ten months too late in 1223, four months too early in 912, one and one-half months too late in 837. The most interesting appearance on the list is the famous comet which preceded the Norman conquest in 1066; contemporary accounts and the Bayeux tapestry give a vivid idea of its splendor, and of the lively apprehension it excited in England. HIND was the first to suggest that this was a return of HALLEY's comet, and his suggestion has now been confirmed beyond doubt. The corrections found for HIND's dates in all cases bring them nearer to the curve published by Dr. ÅNGSTRÖM in 1862, a fact which renders the total failure of this curve for the next return very surprising. (The date for the curve is 1913 instead of 1910.) . . . —*The London Times.*

Minutes of the Meeting of the Board of Directors Held at the Students' Observatory, Berkeley, Cal., on July 10, 1908, at 7:30 p. m.

A quorum was present. In the absence of the President, Director Aitken was elected temporary chairman.

The following were elected to membership:—

Mr. James A. Hennesy, 2718 12th St. N. E., Washington, D. C.

Professor A. G. McAdie, U. S. Weather Bureau, San Francisco, Cal.

The following was elected to institutional membership:—

The Daniel Scholl Observatory, Franklin and Marshall College, Lancaster, Pa.

The Secretary reported that he had sent the comet medals for the last seven awards and had received the acknowledgments of the receipt of two of them from Messrs. Metcalfe and Daniel.

The Library Committee was authorized to purchase one copy of "A Handbook of Learned Societies of North and South America" from the Carnegie Institution of Washington.

It was moved, seconded, and carried that the Publication Committee be allowed the sum of $450 for the printing of the remaining numbers of the *Publications* for the current year. This amount seemed justifiable in view of the report from the Treasurer on our finances at the present time. This report, dated July 7th, was received and placed on file.

The minutes of the meetings of the Board of Directors of March 28, 1908, held at 5:30 p. m. and at 10:00 p. m., respectively, were approved as printed in *Publications*, No. 119.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific, Held in Hearst Hall of the University of California, Berkeley, Cal., July 10, 1908, at 8:00 p. m.

In the absence of the President, Professor C. H. Rieber, Dean of the Summer Session of the University, called the meeting to order and introduced the speaker of the evening, Dr. R. G. Aitken, of the Lick Observatory, who delivered a very interesting lecture upon the subject, "The Story of a Star." The lecture was illustrated by stereopticon views.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Charles Burckhalter . . . . *President*
Mr. W. W. Campbell . . . . *First Vice-President*
Mr. G. E. Hale . . . . *Second Vice-President*
Mr. F. Morse . . . . *Third Vice-President*
Mr. R. T. Crawford (Students' Observatory, Berkeley) . . . . *Secretary*
Mr. R. G. Aitken (Mount Hamilton, Cal.) . . . . *Secretary*
Mr. J. D. Galloway . . . . *Treasurer*

Board of Directors—Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Morse, Richardson, Townley.

Finance Committee—Messrs. Cushing, Crocker, Aitken.

Committee on Publication—Messrs. Townley, Maddrill, Moore.

Library Committee—Messrs. Crawford, Townley, Einarson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Perrine, Townley.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco, California. Subscription price, $5.00 per year.

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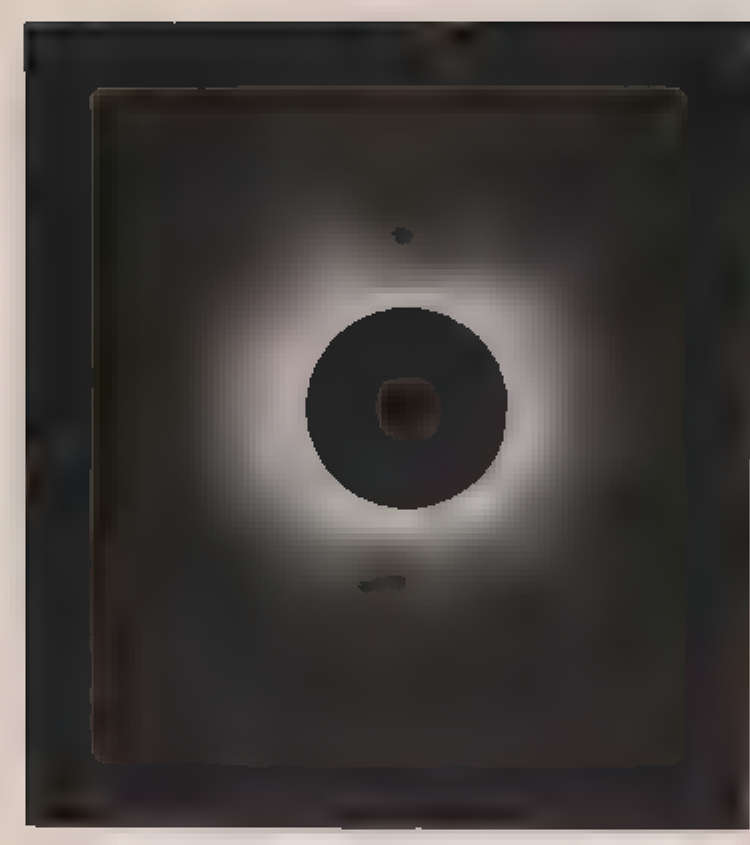
E  W

THE SOLAR CORONA
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PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

Vol. XX. San Francisco, California, October 10, 1908. No. 122

THE NATURE OF AN ASTRONOMER'S WORK.[1]

By W. W. Campbell,

Director of the Lick Observatory, University of California.

For nine years it was my duty and pleasure to show the Saturday night visitors to the Lick Observatory through the great telescope. Their number varied from none on a few of winter's impossible nights up to a maximum of four hundred and thirty. They came from every civilized country, and all trades and professions were represented. They were mainly of those who go about with eyes and minds open. Views through the telescope, descriptions of the instruments, and explanations of celestial photographs received their eager attention.

I was greatly interested in observing human nature under these favorable conditions. My experience with the thirty or forty thousand visitors led me to the conclusions, confirmed again and again, first, that, while interest in astronomical subjects is latent and could easily be aroused in a large proportion of the people, yet the simplest facts of the science, open to frequent observation by everybody, are known to comparatively few; and, secondly, that the nature of an astronomer's work is seldom understood.

At a conservative estimate, the majority of the people are unaware that the stars rise in the east, seem to move across the sky, and set in the west, just as the Sun and Moon do;

[1] Reprinted by special permission, from the June number of *The North American Review*.

or that the summer and winter constellations are different. Very few can explain why the form of the Moon changes from crescent to full, and from full back to crescent, or can say wherein the planets differ from the stars. There are regiments of young men, fresh from school and college, who, knowing amperes, ohms, and volts, can tell you all about the lights in your house, but not one word about the lights in the sky.

The opinion prevails quite generally that an astronomer's duty consists in sitting all night with his eye at the end of the telescope, "sweeping the heavens," in order to discover new bodies—comets, planets, moons, and new stars; and that this is the end and aim of the science. This view is far from the truth. While we in no way discourage the search for new and unknown objects, and, in fact, hail their discovery with delight, we may say that relatively few professional astronomers are thus occupied. The great observatories, with their expensive equipments, cannot afford to engage extensively in such uncertain labor. They leave this work to the small observatories and to the private astronomers, or else they make it a very subsidiary matter. Thus the Lick Observatory, in discovering twenty-seven comets, has devoted certainly less than the one-hundredth part of its resources to that pursuit. The majority of the unexpected comets are, in fact, found by private astronomers, whose four-inch or five-inch telescopes are abundantly powerful for the purpose. The expected returns of periodic comets, on the contrary, are generally detected by professional astronomers. Their mathematical computations tell them when and where to look.

New stars (stars which suddenly appear at points in the sky where none were visible before) and variable stars (those whose brightness varies) are, in the majority of cases, discovered at Harvard College Observatory, for the most part not by direct search, but as the indirect results, or by-products, of an extensive study of the spectra of the stars for another purpose. A few are detected at private and small observatories. Only occasional ones are found at other large observatories, and these are usually detected by chance or by very indirect methods.

It matters little if new stars—comets, satellites, nebulæ, or variable stars—are simply "discovered." That is only the beginning of our interest. There are a hundred million bright stars to be seen in the 36-inch telescope whenever we care to look for them. Of what value is it merely to know that one more star has appeared?

Up to the year 1898 some ten thousand nebulæ had been discovered at the various observatories, and their positions and descriptions are published in a catalogue of nebulæ.[1] The photographs of widely distributed regions of the sky, taken in part by the late Director KEELER, with the Crossley reflector of the Lick Observatory, and continued by Professor PERRINE, indicate that the number not yet discovered, but easily discoverable with this instrument, is in excess of four hundred thousand. These can be found whenever we care to undertake the work. The new ones already discovered, by means of plates taken in the past eight years for other purposes, number nearly a thousand.

The value of the discovery of such objects is not in the discoveries themselves; it is in the opportunity thereby presented for the *thorough study* of those objects. If they are simply discovered and not investigated, the science of astronomy is advanced comparatively little. It is as if EUCLID had learned that there is a science of the circle and the sphere, but had not investigated its laws. It is as if the chemist had discovered that there is an element called oxygen, but had not proceeded to determine its properties; or as if COPERNICUS had been content, like his neighbors, with noting the existence of the principal heavenly bodies, and had not investigated their motions. There certainly have been no more marked cases of successful comet-seeking than those of BARNARD and PERRINE during the few years when they gave a small fraction of their time, on Mt. Hamilton, to this pursuit; but the highest astronomical prizes of the Paris Academy of Sciences were bestowed upon them not so much for their discoveries as for the opportunities thereby afforded for the further efficient study of cometary bodies, in which the discoverers themselves played leading parts.

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[1] The nebulæ are faint cloudlike forms, some of which are masses of glowing gases from which stars, planets and their moons will eventually be evolved.

I fear that the foregoing references to newly discovered bodies have conveyed the impression that our attention is largely devoted to them. This view is erroneous, and I hasten to correct it. We do not overlook the old and well-known bodies, about which we still have much to learn. These familiar objects, illustrating the general principles of the science, and representing world-life in essentially all its stages of development, deserve and receive the major part of our efforts. Generally less than ten per cent of astronomical effort is devoted to the search for and study of new objects. It is not practicable to explain in full the nature of the astronomer's investigations, but a few illustrations will be given in general outline.

For three centuries following COPERNICUS, astronomical study was devoted almost exclusively to the solar system,—to the Sun, planets, and satellites composing this system; their forms and dimensions, their orbital motions and motions of rotation, and the relations of the different members of the system to one another. This work has been brought to a high degree of perfection, in part by astronomers yet living. It would be misleading to say that these problems are completely solved. For example, minute discrepancies in the motions of our Moon, of *Mercury*, and of other members of the system remain unexplained, and from time to time added refinements may be expected for all parts of the system. However, it is now possible to predict, with remarkable accuracy, the positions to be occupied by our rapidly moving planets and their satellites for centuries in the future.

In 1898, WITT, of Berlin, discovered an asteroid,—one of the group of small planets in our solar system whose orbits lie between those of *Mars* and *Jupiter*. He named it "*Eros*." It was the four hundred and thirty-third asteroid to be discovered, and the announcement created no comment. However, it was soon found that its orbit was smaller than those of the other asteroids, and that *Eros* would come much closer to the Earth than any other planet. At the times when the Earth and *Eros* are most favorably situated, the distance between them is only 13,500,000 miles. This is about one third the minimum distance of any other known asteroid. This un-

expected fact, of little importance in itself, was epoch making as a means to an end. It happens that the degree of accuracy with which we can at present measure the distance of the Earth from the Sun, some 93,000,000 miles (the principal astronomical unit of distance), depends upon the closeness of an asteroid's approach to us. By observations of *Eros*, we should, therefore, obtain a threefold more accurate knowledge of the distance of the Earth from the Sun than we now possess. When the asteroid was comparatively close to the Earth, in 1900-1, some thirty observatories throughout the world co-operated in securing a very accurate and extensive series of observations for this purpose. The measurement of the hundreds of photographic plates of *Eros* and the stars in that part of the sky, the computations connected therewith, and the determination of the resulting value of the Sun's distance from us, will require the labor of at least thirty skilled men during five years or more. This case illustrates unusually well the fact that the discovery of an unknown body is valuable substantially in proportion to the opportunity thereby afforded for making useful extensions to our knowledge. Simply to know that there is a planet *Eros*, traveling in a certain orbit, has little more value than as a satisfaction to human curiosity. But to take scientific advantage of the discovery of *Eros* is to improve our knowledge of all celestial distances; or, in other words, to determine with greater accuracy the scale on which the universe is constructed.

Within the past half-century improvements in instruments and methods have enabled us to pass from the problems of our own little system to those of the incomparably more remote and extensive stellar system, and the present tendency of astronomy is strongly in the latter direction.

I wish it were possible to give here an idea of the valuable and extensive investigations which have been made with meridian instruments—instruments which measure the positions of the stars on the celestial sphere as they cross the meridian. At least one half the energies of astronomers in the past one hundred and fifty years have been devoted to making and reducing meridian observations. These have given us our star catalogues, containing the extremely accu-

rate positions of one hundred thousand stars, and the approximate positions of a million more. The data contained in these catalogues are the foundation upon which the entire superstructure of mathematical astronomy is built. These collections of star-positions, acquired at the cost of great skill, patience, and toil, are perhaps the richest of astronomy's possessions. And their values increase constantly with time; for, as the stars are slowly changing their apparent positions on the celestial sphere, and as their rates and directions of motion are determined by comparing their present day positions with their former ones, it follows that the earlier accurate observations have values directly proportional to their age.

Unfortunately these catalogue positions tell us only the direction in which a star lies and nothing at all as to its distance. The component of motion at right angles to the line of sight is expressed in angular measure, and cannot be converted into linear motion,—miles per second, for example,—until the star's distance becomes known. We have approximate knowledge of the distances of only a few dozen stars. Our present means are apparently inadequate to measure the distances, even roughly, of more than a few hundred stars; but half a dozen astronomers are struggling with the problem, and it is hoped that appreciable improvement in methods will result. At no other point in the science is accurate knowledge more keenly needed.

The two foregoing paragraphs refer only to that component of a star's motion which is at right angles to the line joining the star and observer. Now, every star has at the same time a component motion toward or away from the observer, of which the meridian instrument has taken and can take no account. Fortunately the spectroscope is able to measure this component, and eight leading observatories have each a department engaged in observing the brighter stars with a great telescope and spectrograph (an instrument for photographing spectra), in order to determine their motions of approach and recession.

Given the component of motion at right angles to the line of sight as determined by meridian and parallax observers, and the component parallel to the line of sight supplied by

the spectrograph, we could readily ascertain the actual motion of the star *with reference to the observer* However, this would be in itself of little value in a study of the stellar system as a whole, unless we have means of eliminating the effects of the observer's motion, since the observed motion is not the star's motion with reference to the stellar system, but it is a compound of its motion and that of the observer.

Astronomers have known for a century that our solar system as a whole is traveling toward the constellation *Lyra* or *Hercules* and away from the opposite part of the sky, but an uncertainty of at least 10° exists as to the exact direction. Until recently little has been known as to the speed of our motion, the estimates of different astronomers varying from five to thirty miles per second In order to obtain a satisfactory solution of this problem, if possible, the great Lick telescope, with the Mills spectrograph attached to it, has been used three nights per week for the past ten years to secure the photographic observations needed, and the work will be continued several years more. The labor required to measure and reduce the photographs is three or four fold that involved in securing the plates. Observations of the stars visible only in the southern hemisphere are also required before the solution can be made satisfactory, and a branch observatory, located on a mountain top in the northeastern suburbs of Santiago, Chile, is getting these observations, thanks to the generosity of Mr. D. O. Mills.

If we would learn the nature of the stars, whether they are solid, liquid, or gaseous; whether they are new or comparatively old; whether their temperatures are high or relatively low,—we should begin by making a study of our own star—our Sun. It is the only star near enough to present a disk, and therefore to let us study it in some detail All other stars remain as points of light even when the powerful telescopes magnify them three-thousandfold. There are observatories established for the sole purpose of investigating the Sun, and many astronomers are constantly employed in studying the structure of all its visible portions, the laws followed by the heat and light radiated from all parts of its surface, and the conditions indicated by the spectrum of each

part. It is not too much to say that our physical knowledge of the stars would to-day be almost a blank if we had been unable to approach them through the study of our Sun. Several of the most interesting portions of our Sun are invisible, except at times of solar eclipse. Our knowledge of the Sun will be incomplete until these portions are thoroughly understood; and this is the reason why eclipse expeditions are despatched, at great expense of time and money, to occupy stations within the narrow shadow belts in whatever corners of the Earth these events occur.

A score of other departments of our science call for systematic work, according to programmes equally extensive. For example, there are the nebulæ,—their forms, their temperatures, their spectra, their motions, their relations to the stars already existing, and the principles in accordance with which they themselves will in long ages condense and form other stars.

Double stars constitute a large department. The recent work of Professors AITKEN and HUSSEY, of the Lick Observatory, has shown that, on the average, one star in eighteen is attended by a bright companion sun, visible through powerful telescopes, but not at all to the unassisted eye. Observations with the Mills spectrograph of the Lick Observatory, the Bruce spectrograph of the Yerkes Observatory, and other similar instruments, have established that at least one star in six is attended by massive close companions, invisible in the most powerful telescopes. All these systems, both visible and invisible, call for investigation.

There are the variable stars, those thus far discovered numbering more than two thousand. Why are they brighter at one time than at another? The causes in nineteen cases out of twenty are unknown, and the determination of these causes constitutes a great problem. Half a dozen small observatories, extending around the world near the parallel of 39° north latitude, are engaged exclusively in studying the variation of terrestrial latitudes; for it has been shown that the position of the Earth's equator and, therefore, our distance from the equator (our latitude) changes back and forth through a range of sixty feet. A few large observatories are devoting decades to the accurate measurement of the brightness of the stars.

The resources of a dozen observatories are devoted to the photographic charting of the heavens, each photograph requiring accurate measurement and computation—an enormous piece of work, demanding twenty years or more for its completion. A better realization of the magnitude of the labor involved will be gained, perhaps, by calculating that a dozen observatories for twenty years, *on one problem*, is equivalent to one observatory's time and effort for two hundred and forty years.

There are the comets, which excite great public and scientific interest, not only because they are extremely interesting objects, but because they come close to us, and since they come and go, they must be studied while here. How and where did they originate? What is their composition? What conditions prevail in them? In other words, what is a comet, and what is its relation to other celestial objects?

Not to illustrate further, it should be said that these lines of work, as well as the far greater number of unmentioned ones, all bear upon the solution of the two great problems which at present compose the science of astronomy. These problems, perhaps the most profound in the realm of matter, may be stated thus:—

First, a determination of the structure of the sidereal universe; of the form of that portion of limitless space occupied by our stellar system; of the general arrangement of the sidereal units in space, and their geometrical relations to one another; and of their motions in accordance with the laws of gravitation;

Second, a determination of what the nebulæ, stars, planets, satellites, comets, and other members of the universe really are: what are their chemical constitutions; their physical conditions and relations to one another; what has been the history of their development, in accordance with the principles of sidereal evolution; and what has the future in store for them, and for the system as a whole.

Observatories supply accurate time signals wherever telegraph and cable extend. These signals are regulated by observations of stars whose positions have been previously determined by meridian instruments. Many modern boundary

lines between nations are located by means of observations of stars whose exact positions in the sky are defined in the star catalogues. The ship's captain ascertains his latitude and longitude, and therefore the course of his vessel, by observations of the Sun, Moon, and stars, whose positions are prepared for him in advance by astronomers, as a result of their extensive observations and extremely laborious calculations.

That the main results of the astronomer's work are not so immediately practical does not detract from their value. They are, I venture to think, the more to be prized on that account. Astronomy has profoundly influenced the thought of the race. In fact, it has been the keystone in the arch of the sciences under which we have marched out from the darkness of the fifteenth and preceding centuries to the comparative light of to-day.

Who can estimate the value to civilization of the Copernican system of the Sun and planets? A round Earth, an Earth not the center of the universe, an Earth obeying law, an Earth developed by processes of evolution covering tens of millions of years, is incomparably grander than the Earth which ante-Copernican imagination pictured.

It is of priceless value to the human race to know that the Sun will supply the needs of the Earth, as to light and heat, for millions of years; that the stars are not lanterns hung out at night, but are suns like our own; and that numbers of them probably have planets revolving around them, perhaps in many cases with inhabitants adapted to the conditions existing there. In a sentence, the main purpose of the science is to learn the truth about the stellar universe; to increase human knowledge concerning our surroundings, and to widen the limits of intellectual life.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1908.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME

First Quarter	Nov	1,	$6^h\ 16^m$ A.M.	Full Moon	Dec	7,	$1^h\ 44^m$ P.M.
Full Moon	"	7,	11 58 P.M.	Last Quarter	"	15,	1 12 P.M.
Last Quarter	"	15,	3 41 P.M.	New Moon	"	23,	3 50 A.M.
New Moon	"	23,	1 53 P.M.	First Quarter	"	29,	9 40 P.M.
First Quarter.	"	30,	1 44 P.M.				

There will be a lunar appulse on December 7th. The Moon will just miss passing through the Earth's shadow, the nearest approach being 12″, at a time when the Moon is rising in the eastern part of the United States.

There will be a central eclipse of the Sun on December 23d, but the path of central eclipse lies far to the south, almost in Antarctic regions. The eclipse will scarcely be seen at all north of the equator. It is noteworthy for the fact that at the beginning and end of central eclipse, which occur at sunrise and sunset respectively, the eclipse is annular, and for the regions in the middle of the track, where the eclipse occurs near noon, it is total. This is due to the increase in apparent size of the Moon as it rises higher in the sky, causing a diminution in its actual distance from the place of observation on the surface of the Earth. When the Moon is in the zenith it is nearer us by about one sixtieth than it is when on the horizon. The maximum duration of totality is only eleven seconds.

The Sun reaches the winter solstice and winter begins December 21st, 10^h P.M., Pacific time.

Mercury passes inferior conjunction and becomes a morning star on October 28th, and remains a morning star until December 23d, when it passes superior conjunction and becomes an evening star. It reaches its greatest west elongation, 19° 19′, on November 13th, rather a small greatest elongation, as it occurs only a little more than a week after perihelion passage. It rises rather more than an hour and

one half before sunrise at this time, and the interval remains greater than an hour until after December 1st. The planet therefore can be seen in the twilight on clear mornings in the latter half of November. It will be too near the Sun to be seen in December, except possibly the first few days of the month.

Venus rises about three and one half hours before sunrise on November 1st,—that is, at about 3^h A.M.,—but it passed greatest west elongation about the middle of September, and its distance from the Sun diminishes from 38° on November 1st to 31° on December 31st. On November 1st it was nearly 17° north of the Sun, and on December 31st it is only a little more than 2°. These two causes combined cause a rapid diminution of the time between the rising of the planet and of the Sun, so that at the end of December the interval is only a little more than two hours. It passes perihelion on the morning of November 12th, but this causes very little diminution in the apparent distance from the Sun, for the reason that the orbit of *Venus* is very nearly circular, and not like the orbits of *Mercury* and *Mars*, which are relatively very eccentric. *Venus* and *Mars* are in rather close conjunction on the afternoon of November 30th, the former passing 1° 17′ north of the latter.

Mars is now a morning star, rising about two hours before sunrise on November 1st, or at about $4^h\ 30^m$ A.M. On December 31st it rises about three and one half hours before the Sun, or a little before 4^h A.M. During the two months' period it moves about 38° eastward and 14° southward, through *Virgo* into *Libra*, and on November 12th it passes about 3° north of *Spica*, the brightest star in *Virgo*. Its actual distance from the Earth has begun to diminish rapidly, thirty-six million miles during the two months, and its brightness will in consequence increase noticeably; but it will not become a conspicuous object until the late spring of 1909.

Jupiter rises at about $1^h\ 30^m$ A.M. on November 1st, and at about 10^h P.M. on December 31st. It is in the constellation *Leo*, and moves about 5° eastward and southward at a gradually diminishing rate until December 30th, when it becomes stationary, and then begins to retrograde or move westward

Saturn is in good position for observation, being above the horizon until 3^h 30^m A.M. on November 1st, and until nearly midnight on December 31st. It crosses the meridian at about 9^h 30^m P.M. on November 1st, and at about 5^h 30^m P.M. on December 31st. It is in the constellation *Pisces*, and up to December 7th moves about $1°$ westward. It then begins its direct motion, and by the end of the month has moved about one half degree eastward The rings as seen in the telescope appear to diminish in minor axis until December; after that they appear to grow wider, and will broaden out until some time in the summer of 1909; then for a few months they will appear to narrow again, but the narrowing in 1909 will not be as great as in 1908. There will be, on the whole, a progressive broadening of the rings for seven or eight years.

Uranus is in the southwestern sky in the evening. On November 1st it does not set until nearly 9^h P.M., but by the end of December it has nearly reached conjunction with the Sun and sets only about half an hour after sunset. It remains in the constellation *Sagittarius*, but moves about $3°$ eastward away from the "milk-dipper" and π *Sagittarii*, which have served to mark it during 1908.

Neptune rises shortly after 9^h P.M. on November 1st, and shortly after 5^h P.M. on December 31st, having nearly reached opposition with the Sun. It remains in the constellation *Gemini*

NOTES FROM PACIFIC COAST OBSERVATORIES.

Some Results of a Study of the Structure of Photographic Films.[1]

It is well known that the discordances found between the positions of stars on different photographs, or of different images on the same photograph, are much greater than the errors of measurement alone. Could such discordances be eliminated, the gain in the accuracy of positions derived from photographs would be very great.

In my work on the development of methods for deriving stellar parallaxes by photography, this matter of erratic discordances has seemed of first importance, and I have made a study of it.

There are several possible sources for these discordances: –

1. Distortions of the photographic film.
2. Peculiarities of the telescope, including its driving mechanism, seeing, etc.
3. The structure of the image formed in the film.

The distortions of the film have been investigated by a number of astronomers with the result that such distortions appear to be small and not to account for the large discordances which occur in practice. My own investigations on distortion confirm this opinion, and indicate that they are of the order of magnitude of the uncertainties of measurement.

I then adopted a plan which at once eliminated all of the conditions of source 2 and threw the responsibility on source 3. It was to copy on the same plate a number of images of the

[1] Abstract from *Lick Observatory Bulletin*, No. 143.

artificial stars on a pattern plate. The different images were obtained by successive exposures to the pattern plate, shifting the pattern plate a little between exposures. It will be seen that the resulting images should be exactly alike, and that the distances between them should agree exactly, if there is no distortion of the film or no irregularities in form of the images.

Measures of distances made on these laboratory plates showed discordances similar in magnitude to those made on actual star-plates.

The form and structure of the images on the laboratory plates were next examined under a microscope. It was found that instead of being round and exactly alike, as they should have been, the images were quite irregular in form, the irregularities being great enough to cause such discordances as those observed.

These irregularities of form appear to result from vacancies in the gelatine where there are no silver grains. If the exposure is sufficiently prolonged, the star-image is opaque in the center, but there is a surrounding penumbra where these vacancies show. It is my belief that these irregularities of structure are the chief source of the large discordances now found in measures of photographic star-positions. There are also some distortions of the film, but these appear to be small. At any rate, the structure of the film should be made so uniform that we can obtain successive images of a pattern star which agree with one another. Then we shall be in a better position to investigate the actual distortions.

The illustration herewith is an enlargement to 150 diameters of four images copied by successive contact exposure from a single image on a pattern plate. These four images should all be alike, except for such changes as are introduced by the grain and structure of the film on which the copies are made.

It is entirely possible that an increase in the amount of silver in the film will eliminate most of the trouble. A division into finer grains of the silver now present in films should also help materially.

One of our largest dry-plate manufacturers is now experimenting in the direction of improving the structure of the film.

and it is hoped that his efforts will be early successful. One of the most encouraging results of these investigations is the apparent freedom of the positions from errors due to the telescope and seeing.

C. D. PERRINE.

MT. HAMILTON, CAL., September 26, 1908.

THE ORBIT OF THE EIGHTH SATELLITE OF *JUPITER*

From observations extending from January 27th to April 29th of this year, we have derived a set of osculating elements of the orbit of *Jupiter's* eighth satellite, which was discovered last January by MELOTTE at Greenwich. The results show that the motion is retrograde, the inclination of the orbit plane to the equator being about 146°. The orbit is quite eccentric, ϕ being 26°. The satellite's mean distance from *Jupiter* is 0.18 (astronomical units). The periodic time about *Jupiter* is two and a half years.

The osculating elements were derived by LEUSCHNER'S "Analytical Method of Determining the Orbits of New Satellites," which was used here with success in determining the orbit of the seventh satellite. The computation was based upon the supposition that *Jupiter* is the primary and the Sun is the principal disturbing body. This method then gives the osculating orbit for the middle date used (March 8th), in which the attraction of the Sun as a disturbing body during the period covered by the observations (January 27th-April 29th) is fully taken into account.

An ephemeris based upon these osculating elements and the perturbations due to the Sun, computed by ENCKE'S method as adapted to this problem by LEUSCHNER, is in preparation.

R. T. CRAWFORD,
W. F. MEYER.

BERKELEY ASTRONOMICAL DEPARTMENT,
September 23, 1908.

NOTE ON COMET *c* 1908.

Comet *c* 1908 was discovered by Professor MOREHOUSE at the Yerkes Observatory on September 1st.

Two orbits of this comet have been computed at the Students' Observatory. The second set of elements and an ephemeris may be found in *Lick Observatory Bulletin*, No. 139.

The comet is moving in a plane inclined 140° to the ecliptic. Its nearest approach to the Sun occurs on December 25th, when it will be eighty million miles from it. At present it is visible in an opera-glass. It is increasing in brilliancy, and will reach a maximum about October 25th. During October its positions among the constellations will be as follows: On the 1st it passes near *Beta Cephei;* 7th, near *Theta Cephei;* 13th, near *Theta, Iota,* and *Kappa Cygni;* from the 15th to the 31st, through the constellation *Lyra,* passing about 10° east of *Vega* on the 21st. The nearest approach to the Earth, one hundred and twenty million miles, will occur on the 15th of October.

Sturla Einarsson,
W. F. Meyer.

Berkeley Astronomical Department,
September 22, 1908.

Note on the Orbit of β 612.

In *Lick Observatory Bulletin,* No. 101, I published an investigation of the orbit of this binary system which led to a periodic time of 34.4 years. The elements given represented the observed motion to 1906, inclusive, reasonably well, though the run of the residuals gave some evidence of systematic errors, and it was clear that improvements could be effected when observations in the first quadrant became available. The ephemeris for the years following 1906 predicted a steady increase of the apparent distance between the two components with decreasing angular motion until the companion had reached the position given by Burnham at the time of discovery, in 1878. My measures in 1907 and 1908, however, showed little or no increase of distance and very rapid angular motion, so that the residuals in the two years were, respectively,

$$+22^\circ.3, \; -0''.05, \text{ and } +50^\circ.1 \text{ and } -0''.08.$$

It was clear that my orbit was unsatisfactory, and this star was therefore used as one of the illustrations in a course on "Double-Star Astronomy," given this year at the summer session of the University of California. Four graduate students, under my direction, attempted to improve my published elements, using the data given in Burnham's "General Catalogue

of Double Stars" and my recent measures. Considerable improvement was effected by reducing the periodic time to thirty years, with corresponding changes in the other elements, but the residuals for the measures of BURNHAM and HALL in 1878 were nearly 10°, and for my measures in 1908 over 20°. It was also necessary to assume that the earlier observers had greatly over-measured the distance, while I had made as great an error in the opposite direction. We therefore concluded that no satisfactory orbit could be derived from the available data, and Professor LOHSE, of the Potsdam Observatory, has recently expressed a similar opinion.[1]

A recent examination of the original measures by BURNHAM in 1878 and by HALL in 1878 and 1879 has led me to a new discussion of the orbit, based on the assumption that the companion star in those years was not in the first quadrant, as BURNHAM gives it, but in the third, and that the motion by the year 1891 had amounted to 315°, instead of only 135°, as was then naturally supposed. That this is a valid assumption appears from the fact that BURNHAM makes no distinction in magnitude between the two components, while HALL actually gives the third quadrant in his measures in 1879. Other observers, too, find little or no difference in the brightness of the two stars. This assumption gives an orbit with a periodic time of only 22.8 years, which represents the observed positions to 1903 and those of the last two years within the probable error of measure of so difficult a pair. My observations in 1904, 1905, and 1906 are not quite so well represented, but the star in those years was approaching periastron and the apparent distances were found to be only 0″.11, 0″.10, and 0″.13, respectively. The angle measures must therefore be regarded as less exact than those in earlier years. It is also true that very slight changes in the elements produce large changes in the residuals in this part of the curve.

From these investigations I conclude that the shorter period, 22.8 years, is approximately correct. The details of the discussion will be published as a *Lick Observatory Bulletin*.

September, 1908 R. G. AITKEN.

[1] *Publikationen des Astrophysikalischen Observatoriums zu Potsdam*, No. 58, p. 123, 1908.

GENERAL NOTES.

At the meeting of the Astronomical and Astrophysical Society of America held at Put-in-Bay during the latter part of August the following officers were elected for the ensuing year:—

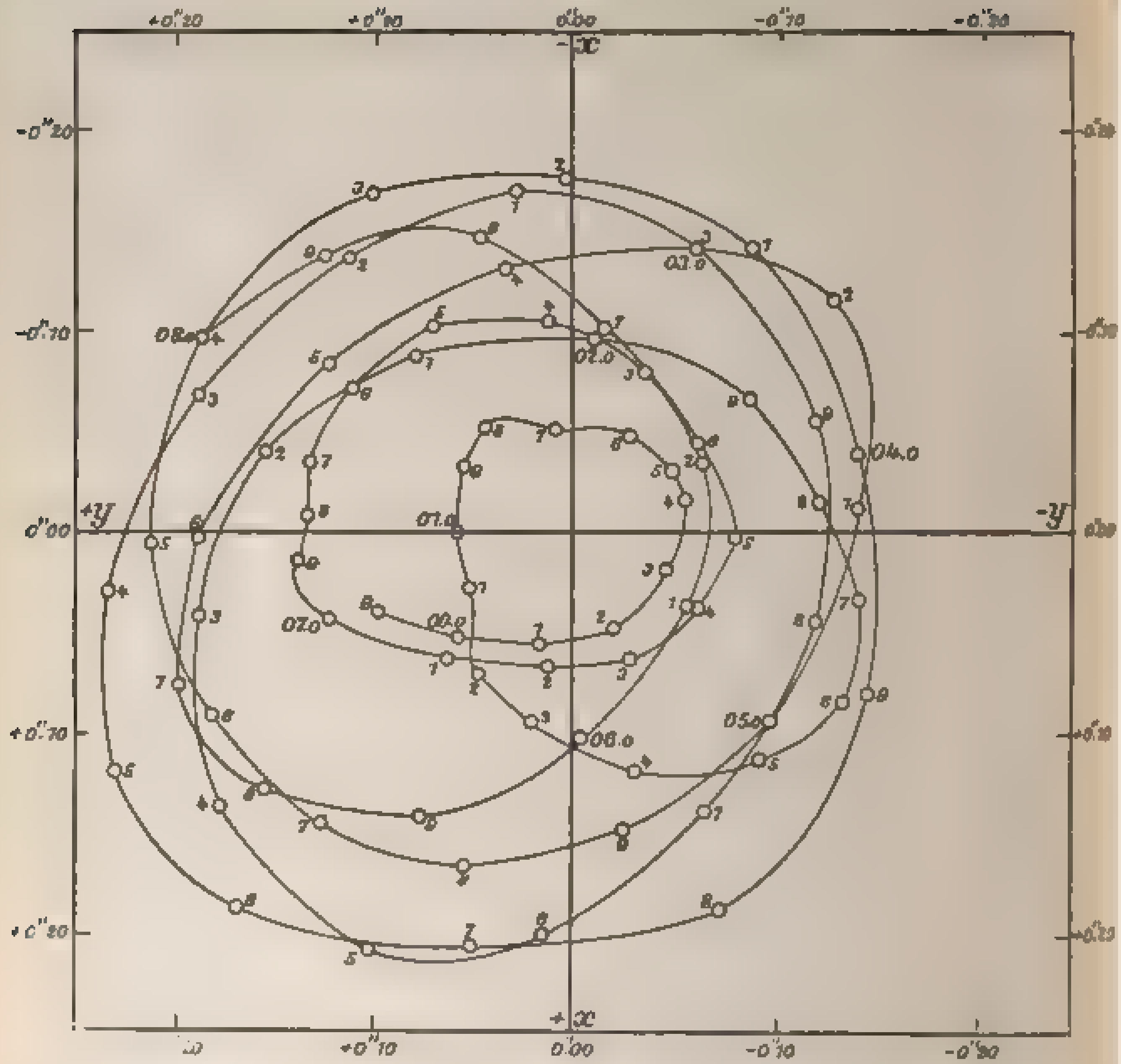
President—E. C. PICKERING.
First Vice-President—G. C. COMSTOCK.
Second Vice-President—W. W. CAMPBELL.
Secretary—W. J. HUSSEY.
Treasurer—C. L. DOOLITTLE.
Councilors—ORMOND STONE, W. S. EICHELBERGER, FRANK SCHLESINGER, W. J. HUMPHREYS.

The Variation of Latitude.—Provisional results of the International Latitude Service during 1907, from observations at the north parallel 39° 8′, are published by Professor ALBRECHT in *Astronomische Nachrichten*, No. 4253. As in his provisional results of previous years, Professor ALBRECHT has employed the observations, by the six stations, of only those sixty-six pairs which have been observed since the start in 1899. (The other thirty of the ninety-six programme pairs were changed at the beginning of 1906.) The same mean places of the stars have been used as in the earlier papers. The deduced path of the pole during the year is traced in the figure here reproduced (from the *Nachrichten*), which shows the path from 1899.9 to 1908.0.

It appears from the eight years' results that the z-term, the term that is independent of the longitude, varies in a simple sine-curve of one-year period. The average of the eight annual z-curves is almost precisely the sine-curve:

$$z = -0''.002 + 0''.046 \sin(t\,360^\circ + 111^\circ.6),$$

in which the time, t, is expressed as a fraction of the year. By this formula, z is zero about ten days before the equinoxes, and reaches its maximum values, $-0''.048$ and $+0''.044$,



about ten days before the summer and winter solstices, respectively. The meteorological explanation of the term seems plausible, therefore, though it is not at all evident why its zero and maximum values should precede, instead of lagging somewhat behind, the equinoxes and solstices. In a later note in the same number, Professor ALBRECHT announces the very interesting and important facts, gleaned from the uncompleted reduction of data obtained at the two new stations at south latitude 31° 55′, that z has the *same sign* at the south parallel as at the north, and seems to have the same magnitude. These facts are seen to add weight to the meteorological hypothesis, as we consider the reversal of seasons in the northern and southern hemispheres.

the Paris Observatory; C. L. W. CHARLIER, director of the

The co-efficients x and y of the longitude terms were also found to be the same in the southern as in the northern hemisphere, so far as could be ascertained at the time of the second note. J. D. M.

Science for September 18th contains an article entitled, "Doctorates Conferred by American Universities" A list of all the doctor's degrees in science conferred in 1908 is given, and, in addition, some statistical studies covering the preceding ten years. But one doctorate in astronomy was given in 1908, and that by Vanderbilt University to JAMES HARRISON SCARBOROUGH, whose thesis was entitled, "The Computation of the Orbit of a Planet."

Algol variables appear to be composed of bodies of small density Dr RISTENPART has deduced (*Astronomische Nachrichten*, No. 4250) the densities of ten of them from the elements of their orbits, and finds that they range from one fiftieth to one third that of our Sun, the densest being those of shortest period. *Observatory*.

Notes from "Science."—Professor GEORGE E. HALE, director of the Solar Observatory of the Carnegie Institution, has been elected a foreign correspondent of the Paris Academy of Sciences in the place of the late ASAPH HALL.

Dr. F. RISTENPART, of Berlin, has been appointed director of the Observatory of Santiago de Chile, as successor to Dr. A. OBRECHT.

Sir GEORGE HOWARD DARWIN, professor of astronomy at Cambridge, has been elected a corresponding member of the Berlin Academy of Sciences.

The Royal Astronomical Society, London, has elected corresponding members as follows. Dr. E. B. FROST, director of the Yerkes Observatory; J. G. HAGEN, S. J., director of the Vatican Observatory; M. BENJAMIN BAILLAUD, director of

Observatory at Lund; and JOHANNES FRANZ HARTMANN, of the Astrophysical Observatory at Potsdam.

Professor HUGO VON SEELIGER, of Munich, has declined a call to the directorship of the Astrophysical Observatory at Potsdam.

The Earl of Rosse. The EARL of ROSSE, a member of the Astronomical Society of the Pacific since 1891, died on the 29th of August last. He was much interested in scientific work and was a regular attendant at scientific meetings. He was twice elected a vice-president of the Royal Society, of which, as well as of the Royal Astronomical Society, he had been a Fellow since 1867. He was one of the senior members of the Board of Visitors of the Greenwich Observatory. His latest contribution to astronomy was an attempt to discover whether the rocks composing the surface of the Moon continued to radiate heat after the Sun's light was cut off during a lunar eclipse. The results of this investigation were submitted to the British Association in South Africa, but further experiments are necessary to obtain a definite conclusion. The father of the late Earl was the distinguished astronomer and sometime president of the Royal Society, who built the great reflecting telescope at Birr, Ireland, by means of which many discoveries of importance were made.

NEW PUBLICATIONS.

Annales de l'Observatoire Royal de Belgique. Nouvelle Séire, Annales Astronomiques Tome X Observations faites au Cercle Meridien de Repsold en 1901, 1902, 1903, 1904, 1905, et 1906 Bruscelles, 1907. 4to. vi + 717. Boards

Annals of the Cape Observatory. Vol II, Part V, Results of meridian observations of the Sun, *Mercury*, and *Venus*, made at the Royal Observatory, Cape of Good Hope, in the years 1884 to 1892. Vol. II, Part VI, Occultations of stars by the Moon, observed at the Royal Observatory, Cape of Good Hope, in the years 1896 to 1906 Edinburgh. 1907. Folio. Paper. Part V, 109 pp.; price, 3s 6d; Part VI, 60 + vi pp.; price, 1s 6d.

Astrographic catalogue. Greenwich section Dec. + 64° to + 90° Vol. II. Measures of rectangular co-ordinates and diameters of star images, Dec. + 72° to + 90°. Edinburgh. 1908. Folio. 996 + xlv pp. Cloth. Price, 30s.

Astronomischer Jahresbericht IX Band Die Literatur des Jahres 1907 Berlin. 1908. 8vo 653 + xxxv pp. Paper

Balcells, P. Mariano. La Observación Solar. Barcelona. 1908. 4to. 143 pp. Paper.

Berliner Astronomisches Jahrbuch fur 1910 mit Angaben fur die Oppositionen der Planeten (1) — (601) fur 1908. Berlin. 1908. 8vo. x + 474 + 112 + 37 pp Paper.

Bohlin, Karl Sur une équation algébrique remarquable se trouvant en rapport à la mécanique céleste. Astronomiska Iakttagelser och undersokningar å Stockholms Observatorium. Band VIII, Nr. 7. Upsala and Stockholm. 1908 4to. 111 pp. Paper.

Catalogue of 1,680 stars for the equinox 1900.0 from observations made at the Royal Observatory, Cape of Good Hope, during the years 1905-1906. Edinburgh 1907 Folio. 44 + xii pp. Cloth. Price, 3s.

Connaissance des temps ou des mouvements céleste pour le méridien de Paris, pour l'an 1910 Publiée par le Bureau

des Longitudes. Paris. 1908. 8vo. viii + 810 + 109 pp Paper.

GRAY, GEORGE J. A bibliography of the works of Sir ISAAC NEWTON. Second edition, revised and enlarged Cambridge. 1907. 8vo. 80 pp. Cloth.

HIRAYAMA, SHIN. Effect of color upon the constant of astronomical refraction. Tokyo. n d. (Reprinted from Tokyo Sugaku Buturigakkwai Kizi, 2d Ser., Vol. IV. No. 17) 8vo 5 pp Paper.

Photoheliographic results, 1874 to 1885. Royal Observatory, Greenwich. Edinburgh. 1907. Folio. 321 + xxiii pp. Cloth. Price, 10s.

Photographische Sternkarten von JOHANN PALISA und MAX WOLF. (Atlas of twenty charts reproduced photographically.) Vienna. 1908 4to. Cloth. Price, 30 Marks.

Publikationen des Astrophysikalischen Observatoriums zu Potsdam No 55, Achtzehnten Bandes, drittes Stuck, Untersuchungen uber die Solarkonstante und die Temperatur der Sonnenphotosphare, von J. SCHEINER Nr. 58, Zwanzigsten Bandes, erster Stuck, Doppel Sterne von O. LOHSE Potsdam. 1908 4to. Paper. Nr. 55, 90 pp.; price, 6 Marks. Nr. 58, 168 pp.; price, 11 Marks.

UGUETO, LUIS. Determinaciones de posicion del cometa Daniell en el observatoire Cajigal (Caracas) Caracas, 1907. 8vo 94 pp. Paper.

OFFICERS OF THE SOCIETY.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

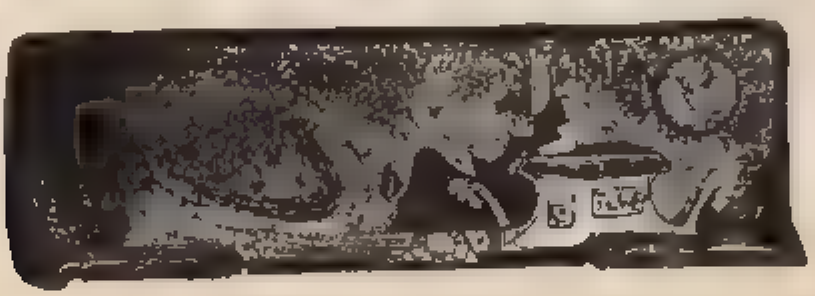
The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

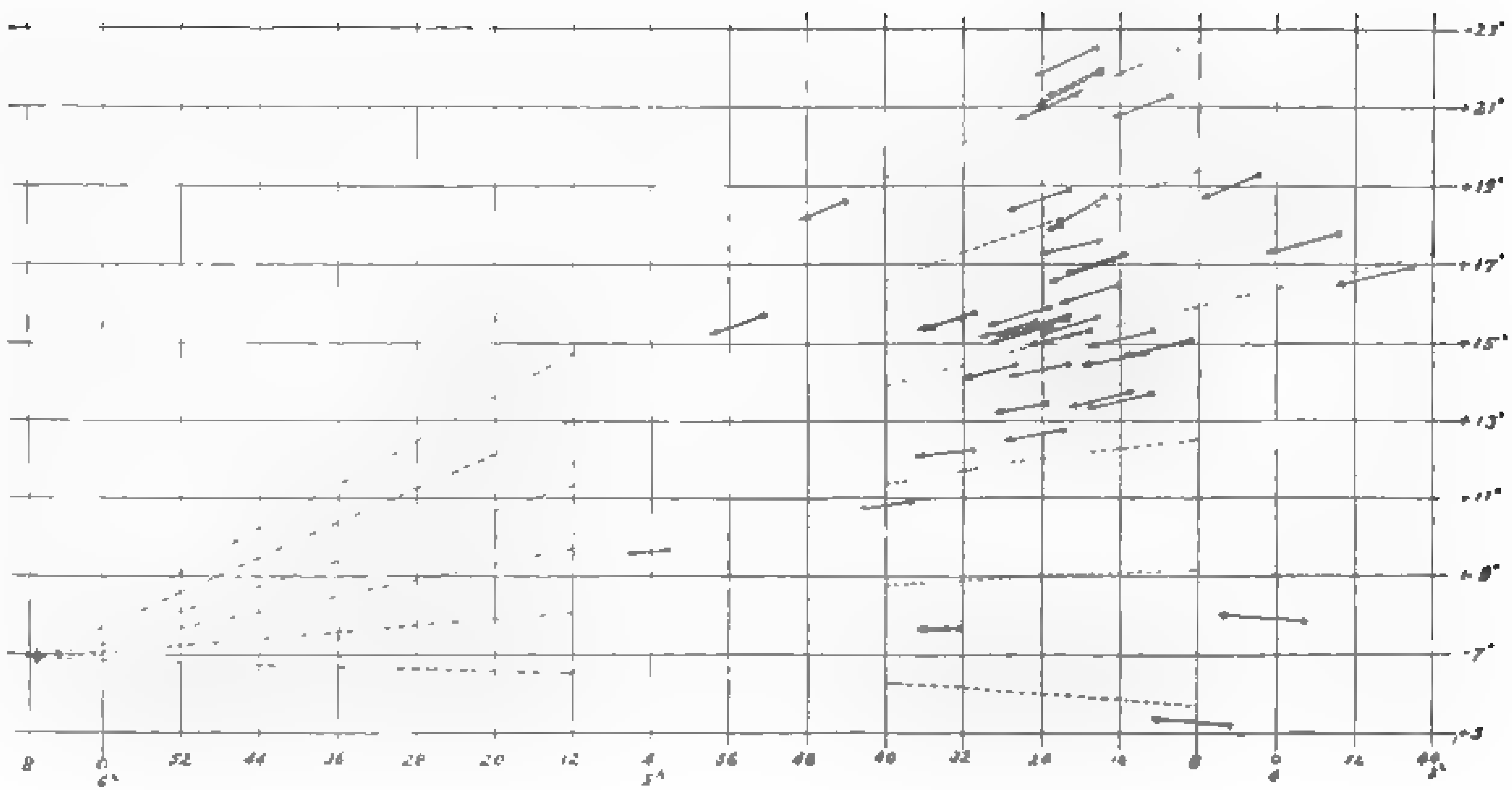
The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco, California. Subscription price, $5.00 per year.





STAR-STREAM IN *TAURUS.*

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XX. SAN FRANCISCO, CALIFORNIA, DECEMBER 10, 1908. No. 123

A REMARKABLE STAR-STREAM IN *TAURUS*.

By W. W. CAMPBELL,

It is well known that many rather widely separated stars possess proper motions,—i. e., motions at right angles to the lines joining the stars and observer,—of essentially the same magnitude and direction; as, for examples, certain stars in the "Big Dipper," and the majority of the stars in the *Pleiades* cluster.

In a recent issue of the *Astronomical Journal*, Professor Boss, of Albany, announced and discussed a most remarkable case of this nature, embracing about forty stars of magnitudes 3½ to 7, in the constellation *Taurus*. Certain of the stars near the center of the group engaged Professor Boss's attention as long as twenty-five years ago, in that their proper motions were seen to be nearly identical. The recent completion of his "Preliminary General Catalogue" of the positions and proper motions of the brighter stars enabled him to recognize thirty-nine, and possibly forty-one, stars whose directions of motion converge to a common but distant point, and whose speeds are such that they will apparently arrive in the vicinity of the converging point simultaneously.

The accompanying illustration expresses the main facts more forcibly than words can do. The present positions of the stars are given by the round dots, and their speeds and directions of motion are indicated by the arrows drawn from the dots. It will be seen that these stars form a widely extended cluster, about 15° in diameter,[1] with marked central condensation;

[1] The right ascensions, extending from 3h 44m to 6h 8m, are given along the bottom of the chart, and the declinations, + 5° to + 23°, along the right edge.

that they are all (with two possible exceptions) aiming approximately for the point of convergence at the left edge of the charted region; that those furthest to the right have in general the largest proper motions; and that with the progress of time the cluster will become more and more condensed.

It should not be concluded that the component stars of the scattered cluster are really approaching each other, as their motion toward the converging point seems to suggest. Professor BOSS's discussion leaves essentially no doubt that the stars are moving along parallel lines; and as these lines extend further and further into space, they appear to unite at the converging point. The lengths of the arrows represent the motions that will occur in the next fifty thousand years. By virtue of the increasing distances of the stars from us, their apparent motions will decrease with time, so a period of sixty-five million years, more or less, will be consumed in traveling to the vicinity of the vanishing point (never actually reaching it), at which time this group would "appear as a globular cluster about 20′ in diameter, and constituted largely of stars of magnitudes 9 to 12, with a well-marked central condensation." The direction of motion is necessarily one of recession from the observer, for the stars are approaching the vanishing point. The direction of motion in space is inclined $27^{\circ}.5$ to the line drawn from the observer through the center of the cluster.

Professor BOSS notes that the stars in the cluster, moving with equal speeds in parallel lines, should have nearly equal speeds in the lines of the observer's sight: a certain average speed for the stars nearest the center of the cluster; related higher speeds for those nearer the radiant; related lower speeds for those further from the radiant; and, if the speed of any one star in the group be observed by means of the spectrograph, the corresponding speeds and parallaxes of all the stars in the cluster may be computed. The spectrographic velocities of three stars in the group have been measured and published by Professor KÜSTNER:—

γ *Tauri*........	$+ 39.6^{km}$	per second.
δ *Tauri*........	$+ 40.8$	" "
ϵ *Tauri*........	$+ 39.4$	" "

From these Professor Boss has computed the speed of the entire group of stars to be 45.6^{km} per second toward the vanishing point; and the average parallax of the group to be 0''.025.

Inasmuch as the extreme outer stars of the group are separated by 15°, their minimum distance apart must be greater than one fourth (15/57.6) the distance separating us from the group,—that is, the most widely separated stars in the group must have a mutual parallax less than four times 0''.025, or 0''.1. Professor Boss reminds us that more than thirty stars of those nearest to our Sun have parallaxes exceeding 0''.1. The vast space through which these thirty stars are extended has a diameter only twice the minimum diameter of the space in which the stars in the cluster under discussion are distributed. It is difficult to account for the origin of such a widely separated group of stars, traveling with equal speeds along parallel lines.

It should be noted that some 15^{km} of the observed speed of recession of the cluster is due to the recession of the solar system away from the cluster.

About seventy-five other stars in the same region, brighter than the seventh magnitude, do not have the distinctive proper motions of the cluster, and are consequently not connected with it.

Nine of the cluster stars have been observed with the Mills spectrograph of the Lick Observatory, as follows:—

Star.	No. of Obs.	Dates.	Velocities.	Remarks.
γ *Tauri*	6	1897–1908	+ 35.8 to + 40.0	Probably variable of long period.
δ *Tauri*	6	1899–1907	+ 38.0 to + 38.8	
κ *Tauri*	2	1904	+ 12 to + 44	Poor spectrum; small weight, perhaps of variable velocity.
68 *Tauri*	3	1905–1908	+ 34 to + 36	
v^1 *Tauri*	1	1904		Very poor lines.
ϵ *Tauri*	6	1898–1906	+ 40.6 to + 37.8	
θ^1 *Tauri*	4	1905–1908	+ 37 to + 38	
θ^2 *Tauri*	6	1903–1908	+ 17 to + 80	Binary.
c Tauri	3	1905–1908	+ 45 to + 66	Measures of 1 line only. Suspected binary.

Six of these stars have velocities in good agreement with the requirements of the cluster theory, and the other three

stars, two of which have spectra with poorly defined lines, afford no evidence in opposition to this theory.

The spectra of twenty-three other stars in the same region of the sky have been observed with the Mills spectrograph, but none of them show speeds in the vicinity of $+ 38^{km}$, with the possible exception of two or three having variable velocities.

THE NORTHERN LIMIT OF THE ZODIACAL LIGHT.[1]

By E. A. Fath.

The boundaries of the zodiacal light are hard to determine because of the faintness of the phenomenon, although the light along the axis is quite strong and can be seen even in cities in spite of the electric illumination. From the usual observations of the boundaries of this light we should expect the light to extend about 20° to the north and south of the Sun. That the zodiacal light is of much greater extent is evident from the observations described below.

In the summer of 1907 Director Campbell, of the Lick Observatory, called the writer's attention to a faint light, which for years has been seen in the summer by various observers at Mount Hamilton, extending along our northern horizon near midnight, and asked that an attempt be made to determine its character. Observations were accordingly begun and continued during the summer of 1908.

The general appearance of the phenomenon when observed near midnight, with a clear sky and no Moon, is that of a flat arch of light with its maximum intensity near the north point of the horizon. At that time of night in the early part of July, 1908, the greatest altitude above the northern horizon was 18°. It extended westward about 40° and eastward to the Milky Way, and was symmetrical with respect to the meridian. At the extremities it was only a degree or two above the horizon, depending on the clearness of the air at such a low altitude. When, however, the observations were

[1] For a complete account see *Lick Observatory Bulletin*, No. 142.

made before midnight the maximum was always to the west of the north point, and after midnight always to the east.

Three hypotheses as to the origin of this light in the north seemed to require examination: 1. That it is an aurora; 2. That it is twilight; and, 3. That it is the zodiacal light. These hypotheses will now be examined.

The aurora hypothesis is not satisfactory for three reasons: 1st. The light is seen only in the summer, during a period of about two months on either side of the summer solstice. 2nd Observations made with a spectroscope on several evenings showed the aurora line, λ 5571, to be visible in all parts of the sky, and no brighter when the spectroscope was pointed to the maximum of the luminous area than when pointed many degrees away and entirely outside it. 3rd Observation shows that the maximum of the light moves with the Sun.

If the light were twilight it seems reasonable to suppose that the mean of the observations would show the maximum intensity to be on or very near the vertical circle passing through the Sun. The mean of twenty-nine observations, taken from June 27 to August 27, 1908, places this maximum 1°.7 farther east along the northern horizon than this vertical circle. Moreover, an observation taken at midnight on July 2d shows that the light could be seen 46° north of the Sun It has usually been stated that twilight ceases when the Sun is 18° below the horizon. At the time of this observation the Sun was 30° below the horizon, and thus 12° lower than the twilight limit. In order to test the question as to the duration of twilight quite a number of observations were made during the summers of 1907 and 1908. They agree in placing the Sun very close to 18° below the horizon at the close of twilight in the evening or the beginning of dawn in the morning. The twilight hypothesis, therefore, does not explain the phenomenon satisfactorily.

Of the three hypotheses that of the zodiacal light remains.

Observations on seven nights showed a direct connection of this light and the ordinary cone of the zodiacal light, a practically straight line forming the northern boundary of both the cone and the light under observation During the summer months the zodiacal light can readily be seen at Mount

Hamilton, both in the west in the evening and in the east in the morning. The connection was seen with both the eastern and western cones.

The 1°.7 displacement, referred to above, of the maximum of the light to the east of the vertical circle passing through the Sun appears significant. If we assume the axis of greatest intensity of the zodiacal light to be in or near the ecliptic, then at midnight at the time of the summer solstice the axis will be perpendicular to the vertical circle passing through the Sun. Before midnight the western angle between the axis and the vertical circle will be less than 90°, and after midnight the eastern angle will be less. In general, before the summer solstice the western angle will average less throughout the night than the eastern, and *vice versa*. Now, taking two points at the same altitude and symmetrically situated with respect to the vertical circle, the one to the west would average nearer the axis throughout the night for observations before the solstice, and therefore be the brighter. In the same way, after the solstice, the eastern one would be the brighter. We might expect, therefore, that before the solstice the maximum observed intensity would be shifted toward the west and after the solstice toward the east, the shift varying with the distance of the Sun from the solstice. Now we find an observed displacement of 1°.7 toward the east, and all the observations upon which this observed displacement depends were made after the solstice. The observations also show a tendency for the displacement to increase with the time. The observations thus agree with the hypothesis.

Another test was then applied. It was found that if the point of greatest altitude was connected with the point of greatest eastern or western extent, and continued until it intersected the ecliptic, these intersections were located from 40° to 105° from the Sun. On plotting the results it was seen that the light was distributed fairly symmetrically with respect to the Sun. It passes 46° to the north and intersects the ecliptic about 70° on either side. This applies, of course, only to the part north of the ecliptic. Assuming symmetry with respect to the ecliptic also we have the lenticular appearance of the zodiacal light The effect of atmospheric absorp-

tion would be to bring the intersections too close to the Sun. The apex of the zodiacal light cone can be seen at various distances from the Sun ranging from 40° to over 100°. This agreement between the observed position of the apex and the position of the intersections is as satisfactory as can be expected from the nature of the objects observed.

The observations were then used in another way. The northern boundary of the cone of the zodiacal light had been located with reference to the stars. This boundary was then located on a celestial globe and extended until it intersected a great circle passing through the Sun and perpendicular to the ecliptic. The mean of fourteen observations of this kind showed that we should expect the zodiacal light to pass 42° north of the Sun. Observations above the northern horizon give 46°.

The writer also examined the observations of JONES,[1] and found that by extending JONES's boundaries of the zodiacal light they would in many cases exceed latitudes of 45° both north and south of the Sun.

From the evidence at hand it seems fair to conclude that the phenomenon observed is the zodiacal light, and that therefore its northern boundary, as seen from the Earth, can be traced 46° north of the Sun, and in consequence the zodiacal light is much greater in extent than has usually been supposed.

In conclusion, it should be stated that as early as 1840, HERRICK,[2] of Yale University, thought he had evidence that he could sometimes see the zodiacal light along the northern horizon in Connecticut, but he made no observations to test his theory. In 1905 Professor NEWCOMB[3] observed the zodiacal light to a distance of 35° north of the Sun; and Professor BARNARD[4] says he has at times seen a faint glow in the summer along the northern horizon at the Yerkes Observatory. So far as the writer has been able to determine these are the only other observations of this nature.

MT. HAMILTON, November 6, 1908.

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[1] *Observations of the Zodiacal Light*, Vol. III of the Report on the United States Japan Expedition, 1856.

[2] *Silliman's Journal of Science*, **39**, 331, 1840.

[3] *Astrophysical Journal*, **22**, 209, 1905.

[4] *Astrophysical Journal*, **23**, 168, 1906.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1909.

By Malcolm McNeill

PHASES OF THE MOON, PACIFIC TIME

Full Moon	Jan.	6, 0h 13m A.M.	Full Moon	Feb.	4, 12h 25m P.M.
Last Quarter	"	14, 10 11 A.M.	Last Quarter	"	13, 4 47 A.M.
New Moon	"	21, 4 12 P.M.	New Moon	"	20, 2 52 A.M.
First Quarter	"	28, 7 7 A.M.	First Quarter	"	20, 6 40 P.M.

Mercury passed superior conjunction late in December, 1908, becoming an evening star, and remains an evening star until February 11th. It reaches greatest eastern elongation, 18° 27', on January 26th. This is a very small greatest elongation, as it occurs only four days before perihelion, and in addition the planet is in the southern half of its orbit during the early part of January. This combination makes the present east elongation a decidedly poor one for visibility as an evening star. Still, during the last half of January and for a few days in February the planet remains above the horizon more than an hour after sunset, and for a few days at the end of January nearly an hour and a half after the Sun has set. It may therefore be seen on a clear evening in the western twilight. The conditions for visibility will be much better about the time of the next greatest east elongation, in May. After passing inferior conjunction on February 11th it becomes a morning star, and by the end of the month is well on toward greatest west elongation, and rises more than an hour before sunrise. It is in conjunction with *Venus* on February 19th.

Venus is a morning star throughout January and February, but is gradually approaching superior conjunction with the Sun, the distance diminishing from 31° on January 1st to 14° on February 28th. The planet is also running south of the Sun. These two causes rapidly diminish the interval between the rising of *Venus* and sunrise from a little over two hours to only about half an hour on February 28th. The planet is also at nearly its maximum distance from the Earth,

and consequently not much above its minimum brightness. However, it may easily be seen in the morning twilight, except possibly during the last few days of February. *Venus* is in conjunction with *Uranus* on January 30th, the latter being only 21′ south of the former.

Mars is also a morning star, rising shortly before 4 o'clock on January 1st and shortly after 3 o'clock on February 28th. Its motion among the stars during the two months' period is 42° eastward and 5° southward from *Libra* through *Scorpio* and the southern extension of *Ophiuchus* into *Sagittarius*. On January 21st it passes about 5° north of the first magnitude red star *Antares*, *α Scorpii*. *Mars* passed its maximum distance from the Earth in the early autumn of 1908, and is now drawing nearer somewhat rapidly, the distance diminishing from 196,000,000 miles on January 1st to 151,000,000 miles on February 28th. In consequence of this its brightness will nearly double, and it will become as conspicuous as a good first-magnitude star; but even at the end of February its brightness will be less than five per cent of its brightness at opposition next September.

Jupiter rises at 10^h P.M. on January 1st and just before sunset on February 28th, as it comes to opposition on the morning of February 28th. It moves westward, retrogrades about 5°, and southward 2°, in the constellation *Leo*, during the two months, toward the first-magnitude star *Regulus*, *α Leonis*, and at the end of the period is about 11° east and south of the star.

Saturn is an evening star throughout the period, setting at about $11^h\ 30^m$ P.M. on January 1st, and shortly after 8^h P.M. on February 28th. It is therefore in good position for observation throughout the two months. It moves about 5° east and 2° north among the stars in the constellation *Pisces*. On January 1st it is about 5° east of the vernal equinox. On January 1st, as seen in the telescope, the apparent width of the rings is not quite one tenth of their breadth. During the year this ratio increases to about one quarter, but toward the close of the year it will diminish to about one fifth.

Uranus on January 1st is an evening star, setting about half an hour after sunset, and is much too near the Sun for

observation even with a telescope. It passes conjunction with the Sun and becomes a morning star on January 7th. By the end of February it rises about three hours before sunrise. Its conjunction with *Venus* on January 30th has already been noted. It moves about 3° eastward in the constellation *Sagittarius* during the two months.

Neptune is in opposition with the Sun and rises at sunset on January 5th. It is moving slowly westward in the constellation *Gemini*, and is a few degrees south and west of *Castor* and *Pollux*, the brightest stars of the constellation.

(SIXTY-FIFTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor Dr. MAX WOLF, Heidelberg, Germany, for his discovery of an unexpected comet on January 2, 1908.

Committee on the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
S. D. TOWNLEY.

SAN FRANCISCO, December 7, 1908.

(SIXTY-SIXTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor D. W. MOREHOUSE, Drake University, Des Moines, Iowa, for his discovery of an unexpected comet on September 1, 1908.

Committee on the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
S. D. TOWNLEY.

SAN FRANCISCO, December 7, 1908.

NOTES FROM PACIFIC COAST OBSERVATORIES.

The Zeeman Effect in the Sun.

In a previous note[1] I described my first observations of the Zeeman effect in sun-spots. Since that time many new results have been obtained.[2] It has been found that when the Nicol is set at such an angle as to transmit the violet component of a doublet in the spectrum of a spot surrounded by a right-handed vortex, it will transmit the red component in the spectrum of a spot surrounded by a left handed vortex. In the laboratory the same effect is produced by reversing the current in the magnet, when observing the doublets along the lines of force. Hence the direction of revolution of the electrified particles in the vortex appears to determine the polarity of the resulting magnetic field, as theory requires. The observed polarity indicates that the sun-spot field is produced by the motion of negative corpuscles.

The above results are obtained when the spots are near the center of the Sun. As they advance toward the limb it might be expected that the doublets would change to triplets, as is usually the case with doublets observed in the magnetic field. As this does not occur, it is of interest to note that all of the spot doublets hitherto observed in the laboratory, with one exception, have been found by Dr. King to appear as doublets not only when observed parallel to the lines of force, but also at right angles to the lines of force. As a matter of fact, a polariscopic study of these lines, made by Dr. King, shows that they are in reality quadruplets, though the components of each of the lines of the apparent doublets are so close together that they cannot be separated in the sun-spot spectrum. The

[1] *Publications A. S. P.*, **20**, 220, 1908.
[2] *Astrophysical Journal*, November, 1908.

line λ 6302.71, when observed at right angles to the lines of force in the laboratory, is a triplet.[1] In the spot spectrum it also appears as a triplet. Since many other lines also appear as triplets in the spot spectrum, it is evident that the light of the spot is partly longitudinal and partly transverse.

A comparison of the separations of spot doublets with those of the same doublets observed in the laboratory gives, in the case of four iron lines, a remarkably close agreement for the relative separations. In the case of titanium, and other elements extending through a considerable range of level in the Sun, there are greater divergences, probably due to the rapid change in the strength of the field in passing upward through the spot. The *D* and *b* lines in the spot spectrum, which represent comparatively high levels, show but little effect of a magnetic field. Hence at the distance of the Earth the spot field would be quite inappreciable, even with very delicate instruments. The strength of the field in spots, at the level represented by the iron doublets, is about 2900 gausses.[2]

It seems possible that the Sun itself, on account of its axial rotation, may also have a magnetic field. The polar rays of the corona, which resemble the lines of force in a magnetic field, long ago suggested this idea to several astronomers. I have accordingly photographed the spectrum of points near the Sun's pole through a Nicol (used with a rhomb) set at various angles. Some of the lines which are double or triple in the spot spectrum appear to undergo slight displacements, with reference to telluric lines, when the Nicol is rotated. I am now endeavoring to determine whether these shifts can be of instrumental origin. If not, they may be produced by the Sun's field.

George E. Hale.

Mt. Wilson Solar Observatory, December, 1908.

"Double Star Astronomy."

In No. 120 of these *Publications* I called attention to a series of papers with the title "Double-Star Astronomy," that were appearing in the *Observatory*. Mr. Lewis has now

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[1] This was at first supposed to be an asymmetrical triplet, but later and better photographs show it to be symmetrical, both in spot and laboratory.

[2] Since the above was written I have obtained photographs of the spectrum of a large spot showing a much stronger field.

reprinted this series under the same title in a handy pamphlet[1] of forty-six pages, which forms an excellent introduction to the study of double stars.

It contains a brief history of the subject, short notices of all the more important double-star observers and publications, the formulæ and examples for two methods of computing an orbit, and some miscellaneous formulæ that are of value.

Of special interest to the present writer are the sections on the separating power of telescopes, on the application of photography to double-star work, and on personal equation. The last-named topic is one on which considerable difference of opinion exists, and some will undoubtedly disagree with the author's conclusions, though I consider them sound doctrine.

As Mr. LEWIS's book will be widely read it seems worth while to correct one statement. On page 23 it is stated, "AITKEN and HUSSEY rarely keep a pair separated over 6″." The numeral should be 5″. Out of 3,237 new pairs so far published only twenty-five have measured distances exceeding 5″.00, and thirteen of these do not exceed 5″.25. Only two pairs (Hu 738, 6″.50, magnitudes 6.3 — 11.5, and Hu 748, 6″.04, magnitudes 6.2 — 12.8) exceed 6″.00. This statement, of course, applies to the closer pair of the system. Occasionally measures are given of one or more additional stars at greater distances.

Another publication of interest to double-star observers is Professor LOHSE's paper, "Doppel Sterne,"[2] published by the Potsdam Observatory. In addition to a good series of measures of selected pairs made with the 11-inch refractor, Professor LOHSE gives the results of his investigations of the motion in thirty-two systems. In a few instances he concludes that no improvement can be made upon existing orbits, but in most instances he computes a new orbit by graphical methods, which in a number of cases he corrects by a least-squares solution. It happens that I have later measures of twenty two of the stars investigated, and I have been interested to see how nearly my measures are represented by the new orbits. In eleven pairs, the residuals are within the limit of error

[1] "Double Star Astronomy," by T. LEWIS, Sec. R. A. S. Taylor & Francis, London, 1908. Two shillings.

[2] See these *Publications*, **20**, 274, 1908.

of observation, in five others (including β 648, of which there is no other orbit) they are fairly satisfactory, but in the remaining six (β 524, β 883, OΣ 235, ξ *Scorpii*, β 416, and 85 *Pegasi*) the residuals in angle average over 23°, and one of the distance residuals, in β 416, exceeds 0″.4.

November, 1908. R. G. AITKEN.

NOTE ON THE BINARY STAR ξ *SCORPII*.

Two orbits for this well-known binary system have recently been published, one by DOBERCK[1] and one by LOHSE.[2] Both are based on practically the same data as my orbit published in 1905,[3] and both computers have adopted the assumption made by me, that the periodic time is about 44.5 years instead of over one hundred years.

The three sets of elements do not differ greatly, but the motion in the apparent orbit has been so rapid during the past three years that even slight variations in the elements lead to decided changes in the residuals derived by comparing the computed and observed positions.

The following tabulation gives my measures made after my orbit was published, and the residuals derived by comparing them with the three sets of elements:—

Date.	θ_0	ρ_0	Nights.	(O–C) A.		(O–C) D.		(O–C) L.	
1905.50	13°.8	0″.18	3	− 5°.6	+0″.02	−19°.1	+0″.03	−14°.8	+0″.0
1906.38	68 .7	0 .23	4	−13 .3	+0 .02	−25 .6	+0 .03	−29 .6	±0 .0
1907.40	108 .2	0 .32	4	− 9 .4	+0 .01	−17 .4	+0 .01	−21 .3	−0 .0
1908.48	125 .8	0 .36	2	−10 .4	−0 .06	−15 .6	−0 .07	−18 .8	−0 .1

These residuals put the correctness of the short period of revolution beyond question, and indicate that the other elements of the orbit are fairly well determined. Further computation will not be profitable until the companion star has passed nearly through the second quadrant.

November, 1908. R. G. AITKEN.

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[1] *Astronomische Nachrichten*, **174**, 257, 1907.
[2] *Pub. d. Astrophysik. Observ.* zu Potsdam, **20**, Pt. I, 124, 1908.
[3] *Lick Observatory Bulletin*, No. 107, 1905.

A New Binary Star.

The bright star 46 *Tauri* (R. A. $4^h\ 8^m\ 10^s$, Decl. $+7° 28'$, 5.3 magnitude) was found to be an unusually close double star when examined with the 36-inch telescope on November 18, 1908. The mean of two nights' measures is:—

1908.90 315°.4 0″.14, 5.7–6.2 magnitudes.

On the first night the telescope was west of pier, on the second night east, and the two angle measures agree within 0°.3, the distance measure on each night being 0″.14. As the star is assigned the proper motion of $-0^s.0020$ and $+0''.023$ in R. A. and Decl. respectively, or 0″.038 in the direction 307°.7, it is obvious that this is a physical system; otherwise it would have been discovered long ago.

Another pair, equally close but fainter, discovered on the same night, is A. G. Berlin B 455 (R. A. $1^h\ 24^m\ 13^s$, Decl. $+22° 19'$, magnitude 6.5). The chances are hundreds to one that it also is a binary system, though the star catalogues do not assign it any proper motion. Measures on two nights give:—

1908.90 126°.2 0″.14, 6.7–7.2 magnitudes.

The two angle measures, made on opposite sides of the meridian, agree within 0°.9, and the distances within 0″.01.

November, 1908. R. G. Aitken.

The Carnegie Institution Observing Station in the Southern Hemisphere.

Director Lewis Boss, of the Dudley Observatory, Albany, and Astronomer Tucker, of the Lick Observatory, sailed from New York last August to Argentina to establish the observing station referred to in the title. The instrumental equipment is to consist chiefly of the Dudley Observatory meridian circle, and the purpose is to observe the accurate positions of all bright stars down to the seventh magnitude, in order to supplement Professor Boss's exactly similar work at Albany, thus making his programme cover the entire sky. The observations to be secured will be utilized in combination and comparison with all similar observations of the same stars made in earlier

years, to determine the positions and the proper motions of the stars. This plan, embracing every star in the entire sky down to the seventh magnitude, is one of the most extensive and ambitious recorded in the history of astronomy; and there is full confidence that the results will be correspondingly valuable.

The site for the observing station was fixed at a point about a kilometer from the center of the city of San Luis, in the west-central part of Argentina. Professor Boss has written that the government officials and the people have been most sympathetic with his aims. The site was provided by the National Government on national property, and in many other ways definite assistance was afforded. Building operations were well under way within two weeks after the astronomers landed in Buenos Aires. Professor TUCKER will be astronomer in charge of the observing station during the three years of work planned for. He will have a large corps of assistants in order that the instrument may be kept busy and the calculations be made promptly.

Albany newspapers report that the ship on which Professor Boss took homeward passage was wrecked shortly after leaving Buenos Aires, and if the reports are trustworthy there must have been cause for great anxiety for a day or two.

W. W. CAMPBELL.

PHOTOGRAPHIC DEFINITION FROM LIGHT OF DIFFERENT WAVE-LENGTHS.

The large size of the photographic images of stars obtained with telescopes of sixty to seventy feet focal length, has led the writer to look for means of reducing them.

Without going into the matter of "seeing" deeply, it may be said that, in all probability, the character of the images depends almost wholly upon *atmospheric refraction*. Assuming this to be the case, star images, for example, formed by yellow light should be much less affected by disturbances of the atmosphere, and consequently be smaller than images formed by light of the short wave-lengths (blue and violet), which affect the ordinary photographic plate most.

Photographs taken with the new 70-foot combination of the Crossley reflector, in the ordinary blue and violet light, and also on orthochromatic plates, using a greenish-yellow color screen, show that the star images which have been formed by yellow light are much smaller than those formed by the ordinary blue and violet light. Similarly, photographs of the Moon and planets are sharper in yellow than in blue light.

Extension of this reasoning points to the deep red part of the spectrum as being favorable for the production of still smaller images and better definition. In photographic work on bright objects, such as the Sun, Moon, and the brighter stars and planets, the use of light of great wave-length is entirely practicable.

A consideration of *visual* definition seems to point to an analogous effect there, although to a less degree, owing to the greater wave-lengths to which the eye is most sensitive.

A detailed account of the experiments already concluded, as well as some still in progress, will be published shortly in a *Lick Observatory Bulletin*.

C. D. PERRINE.

MT. HAMILTON, CAL., December 5, 1908.

EIGHTEEN STARS WHOSE RADIAL VELOCITIES VARY.

In the progress of the work with the three-prism Mills spectrograph at Mt. Hamilton, and of the D. O. Mills Expedition to the southern hemisphere, eighteen stars have recently been found to have radial velocities which vary, on account of the gravitational influence of an invisible but massive companion in each system, except that in case of one star, 70 *Ophiuchi*, a well-known visual double star, the companion is visible. A list of these stars, with data concerning their positions, number of observations, total range of observed velocities, and discoverers of the variations, is given below. Only in the case of 70 *Ophiuchi* is the revolution period known,—in that case eighty-eight years. Detailed data concerning the observations are contained in a *Lick Observatory Bulletin* now in press.

Star.	R. A.	Dec.	Type.	Observed in.	No. of Obs.	Velocity.	Discoverer
γ Persei	$2^h\ 57^m.6$	$+53°\ 7'$	G	1897 to 1908	11	-2 to $+7^{km}$	MOORE.
ξ Tauri	3 21 .8	+ 9 23	A	1903 to 1908	5	−62 to +36	CAMPBELL.
θ_2 Tauri	4 22 .9	+15 39	A	1903 to 1908	6	+17 to +74	MOORE.
l Eridani	4 33 .6	−14 30	I	1900 to 1908	6	+33 to +43	MOORE.
ζ Aurigæ	4 55 .5	+40 56	K	1898 to 1908	7	± 0 to +25	WRIGHT.
ρ Orionis	5 8 .1	+ 2 45	I	1902 to 1908	6	+33 to +50	MOORE.
ζ Can. Maj.	6 16 .5	−30 2	B	1906 to 1907	12	+11 to +38	PADDOCK.
β Can. Maj.	6 18 .3	−17 54	B	1904 to 1908		+27 to +41	ALBRECHT.
ν Puppis	6 34 .7	−43 6	B	1904 to 1908	8	+20 to +35	WRIGHT.
τ Puppis	6 47 .4	−50 30	K	1903 to 1907	6	+30.4 +40	CURTIS.
o Velorum	8 37 .4	−52 34	B	1904 to 1908	11	+10 to +27	CURTIS.
d Carinæ	8 38 .5	−59 24	B	1907	6	+38 to +72	
q Velorum	10 10 .6	−41 37	A	1904 to 1907	4	− 2 to +25	PADDOCK.
ν^2 Draconis	17 30 .3	+55 14	A	1902 to 1908		−23 to − 4	ALBRECHT.
70 Ophiuchi	18 0 .4	+ 2 32	K	1897 to 1908	8	−10 to − 7	
111 Herculis	18 42 .6	+18 4	A	1902 to 1908	6	−26 to −64	WRIGHT.
φ Cygni	19 35 .5	+29 56	I	1907 to 1908	4[1]	± 0 to −24 ± 0 to +30	PLUMMER. CAMPBELL.
υ Octantis	21 30 .4	−77 50	K	1904 to 1907	8	+27 to +36	WRIGHT.

[1] Two components visible.

W. W. CAMPBELL.

December 7, 1908.

APPOINTMENTS.

Mr. E. A. FATH, Fellow in the Lick Observatory, has been appointed Assistant in the Solar Observatory of the Carnegie Institution, dating from July 1, 1909. W. W. CAMPBELL.

Director W. W. CAMPBELL, of the Lick Observatory, has been invited to give the Silliman Lectures in Yale University for the academic year 1909-1910. The course will consist of ten lectures, dealing with the results of Professor CAMPBELL'S work in measuring the radial velocities of stars by means of the spectroscope and the solution of several fundamental problems of astronomy as based upon these motions. The lectures will probably be given in the fall of 1909. J. H. MOORE.

GENERAL NOTES.

The Parallax and Proper Motion of the Double Star Krueger 60. The double star known as *Krueger 60* is of unusual interest for several reasons. It is a faint star, the B. D. magnitude being only 9.0, and so wide that no appreciable relative motion of its three components was to be expected within a century. The first accurate measures were made by BURNHAM—who in fact discovered the closer pair—in 1890, and when his results were compared with those of DOOLITTLE, the next observer, in 1898, it was found that the distance of the wide pair had increased from $26''.8$ to $34''.4$, while the close pair showed a decrease in position angle of nearly 40° with increase of distance of nearly $0''.9$. It therefore appeared probable that the close pair was a binary in rapid motion, and that it had a strong proper motion as well. The combination of rapid orbital motion, strong proper motion, and large apparent angular separation indicated that the pair, in spite of its faintness, was one of our near neighbors in space, and observations for parallax were accordingly instituted at the Yerkes Observatory, both visually, by BARNARD, and photographically, by SCHLESINGER. The latter's preliminary results were published in the *Astrophysical Journal* for September, 1904. They ranged from $+0''.226$ to $+0''.301$, the mean being about $0''.25$.

Professor BARNARD's very complete discussion has now been published in the *Monthly Notices R. A. S.* (Vol. LXVIII, No. 9). The determination of parallax and proper motion of *A* rests upon his observations with the 40-inch telescope of the wide pair *AC* made in the years 1900 to 1905, inclusive. The solution of the seventy-six equations of condition gives the value $\pi = +0''.249 \pm 0''.0105$. For comparison, Dr. SCHLESINGER's final results[1] are given, and also, in a postscript, Dr. H. N. RUSSELL's value obtained from photographs with the Cambridge (England) refractors.

[1] Based on a discussion (not yet published) of nineteen plates taken at the Yerkes Observatory in the years 1903–1906.

The three values are:—

SCHLESINGER	$+0''.248$	$\pm 0''.009$
BARNARD	$+0\ .249$	$\pm 0\ .010$
RUSSELL	$+0\ .258$	$\pm 0\ .013$

The excellent agreement of these independent determinations is the best possible evidence of their accuracy. We may therefore assert with confidence that *Krueger 60* is our close celestial neighbor, light requiring only a little over thirteen years for its journey across the intervening space.

For the proper motion, BARNARD gives the value $0''.968$ in $246^\circ.49$. He adds an interesting discussion of the irregularity of the proper motion of the star *A*, due probably to its orbital motion about the center of gravity of the pair *A B;* also, all his micrometer measures to date, including those of some more distant stars. The angular motion of the close pair in the eighteen years since its discovery has amounted to 74°. The apparent distance seems to have reached its maximum value about the year 1904, and is now diminishing. It may therefore be possible to form some estimate of the periodic time before many years.

R. G. A.

Tempel$_3$-Swift Comet.—On September 29th, M. JAVELLE, at Nice, rediscovered the Tempel$_3$-Swift comet. Its observed position differed over 15^m in Right Ascension and nearly $1^\circ.5$ in Declination from the computed position according to MAUBAUT'S ephemeris. Perihelion passage occurred on September 30th. This comet was discovered by TEMPEL in 1869, and when rediscovered by SWIFT in 1880 was found to move in an ellipse with a period of five and one-half years. The comet was not found at its return in 1874, nor at any of the returns since 1880, except in 1891, when it was rediscovered by BARNARD.

Notes from "Science."—Dr. S. TSCHERNY, of Kiev, has been appointed director of the university observatory in Warsaw.

The Astronomical and Astrophysical Society of America will hold its next meeting in the summer of 1909, probably at the Yerkes Observatory. The exact date has not yet been

fixed, but it is expected to precede by a few days the Winnepeg meeting of the British Association for the Advancement of Science, which will open on August 25, 1909.

Mr. ANDREW GRAHAM, from 1864 to 1903 first assistant at the Cambridge Observatory, known especially for his work on the Cambridge star catalogue published in 1897, died recently at the age of ninety-three years.

We regret also to record the deaths of Dr. JOHN M. THOME, director of the Cordova Observatory since the retirement of Dr. GOULD; and of Mr. ARCHIBALD J. LITTLE, who did valuable geographical work in the interior of Asia.

In the November *Astrophysical Journal,* Messrs. A. FOWLER and A. EAGLE, of the Imperial College of Science and Technology of London, show that a spectrum of linear dispersion on any reasonable scale can be obtained photographically from a prismatic spectrum plate by setting the two plates at proper distances from the lens and tilting them at definite angles. Formulæ are given. An example shows the remarkable accuracy obtained with ordinary apparatus.

J. D. M.

Cecil Goodrich Dolmage.—The following clipping from the *London Times* announces the death of Dr. C. G. DOLMAGE, a member of the Astronomical Society of the Pacific since 1899:—

"The death of Dr. CECIL G. DOLMAGE, author of 'Astronomy of To-day,' a work which has been widely praised, has come as a sad blow to his numerous friends in Dublin and in London, where he had resided for some years past. He took high honors at Trinity College, Dublin, in modern history in 1893, and, devoting himself to intellectual pursuits, accomplished for astronomy, his favorite study, much useful work by his wide knowledge and facile pen. Some eighteen months ago, when on a trip to Italy, he fell dangerously ill; and, though hopes of recovery were entertained, he fell into a steady decline. He was a Fellow of the Royal Astronomical Society and many other learned societies at home and abroad. A man of a singularly truthful and upright nature, of modest manner, and of noble mind, his death will be mourned by many men of varied types whom his ability and personality attracted to him."

NEW PUBLICATIONS.

Annales de l'Observatoire Astronomique de Zô-sè (Chine). Tome II. Année 1906. Chang-Hai, 1908. 4to. 62 pp. Seven plates. Paper.

Atlas Stellarum Variabilium. Series sexta. Composita a I. G. HAGEN, S. I. BEROLINI. 1908. Folio. Cloth.

Beitrag zur Bestimmung der Konstanten der Physischen Libration des Mondes. II. Reihe der Heliometrischen Messungen in Kasan. Ausgeführt von A. MICHAILOWSKI. Bearbeitet von Dr. MAX VÖLKEL. Kasan. 1908. 4to. 46 pp. Paper.

BROWN, ERNEST W. The inequalities in the motion of the Moon due to the direct action of the planets. Cambridge. 1908. 4to. xii + 92 pp. Cloth.

GOOS. FRITZ. Der Spektroskopische Doppelstern Capella. Inaugural Dissertation. Bonn. 1908. 4to. 50 pp. Paper.

HIRAYAMA, K. Declinations and proper motions of 246 stars. Annales de l'Observatoire Astronomique de Tokyo. Tome IV, 1 fascicule. Tokyo. 1907. 4to. 195 pp. Paper.

LUDENDORFF, H. Der Veränderliche Stern R Coronæ Borealis. Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Potsdam. 1908. 4to. 61 pp. Mit 7 Tafeln. Paper.

MORRISON, HUGH ALEXANDER. Preliminary check list of American almanacs 1639-1800. Library of Congress, Washington. 1907. 4to. 159 pp. Cloth.

NICOLIS, UGO. Sul cerchio meridiano dell'Osservatorio de Modena. Pubblicazioni del r. Osservatorio Geofisico di Modena. Modena. 1907. Folio. 13 pp. Paper.

PUISEUX, P. La terre et la lune forme extérieure et structure interne. Paris. 1908. 8vo. 176 pp. 51 figures. Paper.

Royal Observatory. Results of the astronomical observations made at the Royal Observatory, Greenwich, in the year 1906. Edinburgh. 1908. Folio. cxliv + 116 + 92 + 180 pp. Boards.

Solar Physics Committee. On the general spectra of certain type stars and the spectra of several of the brighter stars in the green region. London. 1908. 4to. 46 pp. One plate. Boards. Wyman and Sons. Price, 3s.

Minutes of a Special Meeting of the Board of Directors of the Astronomical Society of the Pacific, Held in Room 601 Merchants Exchange Building, San Francisco, Monday, October 12, 1908.

The meeting was called to order at 4:30 P.M. by President Burckhalter. The following directors were present: Aitken, Burckhalter, Campbell, Crawford, Cushing, Galloway, Morse, Richardson, Townley.

Moved and seconded that the action of the President and Secretary in sending requests for nominations for the award of the Bruce Medal for 1909 be approved. Carried.

The following were elected to membership:—

Mr. G. T. Webster........Box 782, Globe, Arizona.
Mr. Edwin G. Benkman..2267 Turk Street, San Francisco.
Mr. Edwin I. Barnes.....R. F. D. No. 1, Chanute, Kansas.
Mr. John A. Langstroth. Perry Street and Grand Avenue, Oakland.

Moved and seconded that the matter of revising the By-Laws preparatory to their re-publication be referred to the Committee on Publication, to report at the next meeting. Carried.

Mr. Cushing made an oral report on the proposition of moving the library to San Francisco. No action was taken.

The resignation of Mr. Galloway from the position of Treasurer was presented. Upon motion, duly seconded, the resignation was accepted, to take effect upon the qualification of his successor.

Moved and seconded that the Secretary cast the ballot for the election of Mr. Richardson to the position of Treasurer. Carried. The ballot was cast and Mr. Richardson declared elected.

Moved and seconded that, beginning with the month of October, the salary of the Treasurer be fixed at $10 per month, and that the salary of the Secretary be fixed at $10 per month. Carried.

Moved and seconded that the President and Chairman of the Finance Committee be authorized to compromise with the Rhine-Moselle Fire Insurance Company at the best terms obtainable. Carried.

Adjourned.

Minutes of the Meeting of the Board of Directors, Held in Room 601 Merchants Exchange Building, San Francisco, Cal., November 28, 1908, at 2 o'clock P.M.

President Burckhalter presided. The following directors were present: Burckhalter, Crawford, Cushing, Galloway, Morse, Richardson, Townley.

Moved and seconded that the President appoint a permanent medal committee of two; this committee to have charge of all matters con-

cerning the procuring of medals. Carried. The President appointed the following committee: F. R. ZIEL (chairman), R. T. CRAWFORD.

The Secretary reported the receipt of an appreciative letter from Mr. JOHN GRIGG acknowledging the receipt of the comet medal that had been awarded to him.

Moved and seconded that the Treasurer be authorized to secure a safe deposit box at the Crocker National Bank; the rental to be $4.00 per annum. Carried.

Moved and seconded that, according to the By-Laws, the Treasurer give a bond in the sum of $500, furnished by two individual sureties, or one security company; the bond to be approved by the President. Carried.

Chairman CUSHING, of the Committee on Location, made a verbal report.

Moved and seconded that the January meeting of the Society be held at the Chabot Observatory. Carried.

By ballot, the eighth award of the Bruce Medal, for the year 1909, was made. The name of the recipient is not to be made public until after January 1, 1909.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE STUDENTS' OBSERVATORY, BERKELEY, CAL., NOVEMBER 28, 1908, AT 8 O'CLOCK P.M.

The meeting was called to order by President BURCKHALTER.

Moved and seconded that the minutes of the last meeting, as published in the *Publications*, be approved. Carried.

There being no further business, the President introduced Dr. JOSEPH H. MOORE, of the Lick Observatory, who delivered a lecture upon "Variable Stars." At the conclusion of this lecture Dr. SIDNEY D. TOWNLEY, of Stanford University, was introduced and gave a lecture on "Variation of Latitude." Both lectures were illustrated with stereopticon views.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Charles Burckhalter . . . . *President*
Mr. W. W. Campbell . . . . *First Vice-President*
Mr. G. E. Hale . . . . *Second Vice-President*
Mr. F. Morse . . . . *Third Vice-President*
Mr. R. T. Crawford (Students' Observatory, Berkeley) . . . . *Secretary*
Mr. R. G. Aitken (Mount Hamilton, Cal.) . . . . *Secretary*
Mr. D. S. Richardson . . . . *Treasurer*

Board of Directors—Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Morse, Richardson, Townley.

Finance Committee—Messrs. Cushing, Crocker, Aitken.

Committee on Publication—Messrs. Townley, Maddrill, Moore.

Library Committee—Messrs. Crawford, Townley, Einarson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Perrine, Townley.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 19[illegible]3, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three-fourths only of such dues; when elected during the third quarter, he shall pay one-half only of such dues; when elected during the last quarter, he shall pay one-fourth only of such dues; provided, however, that one-half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of Life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY

(February, April, June, August, October, December.)

Published by the Astronomical Society of the Pacific at 601 Merchants Exchange Building, San Francisco, California. Subscription price, $5.00 per year.

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